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ABSTRACT

This is the first of three volumes which presents the Committee on Biomedical and Behavioral Research Personnel's examination of the educational process that leads to doctoral degrees in biomedical and behavioral science (and to postdoctoral study in some cases) and the role of the National Research Service Awards (NRSA) training programs in it. Volume 1 of the Committee's report looks at (1) the role of NRSA programs in the education pipeline, including the historical trends, NRSA program structures, and a statistical overview of NRSA training programs; (2) the current market for biomedical and behavioral scientists and the recent trends in the labor market for each; (3) the future labor market for biomedical and behavioral research personnel; (4) measuring the effectiveness of NRSA training programs; and (5) the recommendations for research in testing a research training program's performance in enriching research careers and increasing the volume and quality of their output. An appendix contains an examination of the emerging biotechnology industry, data needs for program evaluation, and 24 tables summarizing employment trends. (GLR)

BIOMEDICAL AND BEHAVIORAL RESEARCH SCIENTISTS: THEIR TRAINING AND SUPPLY

Volume I: Findings

Committee on Biomedical and Behavioral Research Personnel

Office of Scientific and Engineering Personnel
National Research Council

in collaboration with the
Institute of Medicine

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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BIOMEDICAL AND BEHAVIORAL RESEARCH SCIENTISTS: THEIR TRAINING AND SUPPLY

Volume I: Findings

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PREFACE

This is the ninth report examining issues related to the NRSA research training program. The first committee was convened in 1975 as a result of the National Research Service Award (NRSA) Act of 1974, which mandated that postdoctoral training programs funded by the National Institutes of Health (NIH) and the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA) be restricted to trainees intending to enter a career in research. The NRSA Act was passed at a time when the Office of Management and Budget was challenging the need for postdoctoral research training programs. Although a proposal to phase out funding for all research training programs was unacceptable to the Congress, substantial reforms within the training process were made, including a payback provision for trainees who subsequently selected a career outside of research after the training fellowship.

Another stipulation of the NRSA Act was for the National Academy of Sciences to conduct an ongoing study of training programs and periodically report national needs for biomedical and behavioral research personnel. In the eight previous reports mechanisms were developed to analyze market demand in order to estimate the work force needed to ensure the future viability of biomedical and behavioral research. Consequently, an extensive data base has been developed in addition to analytical models designed for quantitative analyses.

This committee was convened in November 1988 and given only eight months to prepare a report. It has proven to be a most exciting undertaking at a particularly critical time for the biomedical and behavioral sciences in the United States. Significant advances are occurring, and the future is filled with promise for even greater developments in biomedical research leading to an understanding of the fundamental causes of a variety of diseases--from Alzheimer's to cancer--as well as to developing advanced therapies based on this understanding of the etiology and pathophysiologic mechanisms of disease.

There is much work to be done, but will there be sufficient personnel, sufficiently trained, to do it? Factors to be considered in answering the question include:

- the quality of the American school system in educating and encouraging students toward a career in the sciences;
- identifying and correcting the reasons for a continuing dearth of minorities entering careers in research; and
- assessing the relative value and effectiveness of training programs and institutional training grants in producing successful researchers.

The desirability of selecting a career in research also must be examined. Present and future budgetary projections, resulting in decreasing numbers of grants funded by NIH, almost certainly will have a detrimental effect on the attractiveness of an academic research career. It is also necessary to evaluate the effect of the emerging biotechnology industry on the demand for scientists trained by NIH and universities; the impact of industry on standard biomedical and behavioral science research programs; and the role of industry in the training process. Budgetary constraints have also focused interest on health services research because of the size of the health care industry, its proportion of the gross national product, and the intent of government to decrease the amount of money being spent on health care.

Given this environment and the limited time and resources available, this committee sensed that it should do something different from the other committees to date. Specifically, the committee wanted to:

- o reexamine and improve the labor market models used to analyze future requirements for research personnel;
- o review the literature concerning NRSA program evaluations and evaluation methodology and develop a foundation for future NRSA program evaluations;
- o review literature and existing data sets to better define scientific productivity--in academe as well as in industry--as a means to measure NRSA program success;
- o call attention to issues related to the program of study for physician/scientists; and
- o reflect upon the role of the committee itself and make recommendations for future studies.

Essays addressing these special interests accompany the projections of national needs for biomedical and behavioral research scientists. Thus, Chapter 1 contains a discussion of primary and secondary school education and the points where career decisions are formulated; models are presented to aid in understanding the interventions that must be developed for increased recruitment of minorities into careers in the sciences. Chapters 3 and 5 contain a discussion of the role of the physician/scientist and call attention to the need to carefully examine the program of study of the institutional training grants that serve as the single largest source of research training for the physician. In addition, special papers were commissioned to buttress the committee's deliberations and recommendations. Lloyd H. Smith has provided a concept paper regarding the training and role of the physician/scientist in the modern research arena; Georgine Pion has assessed the evaluation of training programs sponsored by NIH; Elizabeth McGlynn has contributed an overview of health services research; and Helen Gee has addressed the complex task of defining scientific productivity, which is so important for the evaluation process. The committee hopes that it has achieved its goals and that the reader will find this an interesting and provocative report--one that will stimulate new areas of interest for the committee and perhaps new areas of research.

As chairman of the committee, I express my appreciation to the staff members who have worked long and hard within extraordinary time constraints to accomplish our assigned task. I also express my appreciation to the committee members who have given unselfishly of their time by participating in the three meetings in Washington and in the writing, rewriting, and analyzing of this report. The entire committee thanks all those other individuals and organizations who have contributed to our discussions and data base.

Gerald S. Levey, M.D.
Chairman, Committee for Biomedical
and Behavioral Research Personnel

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EXECUTIVE SUMMARY

THE COMMITTEE'S INVESTIGATION

This is the ninth report to Congress mandated by the National Research Service Awards (NRSA) Act of 1974, but it is the first report submitted by the Committee on Biomedical and Behavioral Research Personnel. Its predecessor, the Committee on National Needs for Biomedical and Behavioral Research Personnel, produced eight reports and was then disbanded following a 1986 conference that is discussed below. The new committee represented an opportunity for a fresh start, and its members and staff have adopted a sharply different approach to the issue. In particular, this report moves toward a substantially greater emphasis on qualitative issues than heretofore, especially with respect to evaluating the merit of training programs and the productivity of individual careers. This shift in direction reflects the strong recommendation of a panel of experts (see below) but has been constrained by limited time and money: the committee has recommended a program of research, but has been unable to implement it. A mechanism by which NIH can get the work done is also recommended.

The current committee first met in December 1988. The time schedule required that a draft report be completed by July 1989. As a result, the report differs from earlier versions in ways that were undesirable, but unavoidable. One major departure from previous committee efforts is the abandonment of a formal projection model for physician/scientists. The committee felt that the existing data are inadequate to properly define and track physician/scientists; without a historical data series it was impossible to build a credible model. The committee has also had to forego any serious consideration of dental, nursing, and health services research in the report, although it did commission the paper on health services research that is contained in Volume III of this report. (Volume II contains an updated and enlarged version of the set of tables that appeared as an appendix of the 1985 report.) If the organization and timetable that are recommended for the 1993 report are adopted, these topics can be reintroduced in it.

In the time that it had, the committee elected to examine the educational process that leads to doctoral degrees in biomedical and behavioral science (and to postdoctoral study in some cases) and the role of NRSA training programs in it. Conclusions from this examination are provided, beginning on page 3. The congressionally mandated analysis and a new and broader projection of the labor market for biomedical and behavioral scientists are described in Chapters 2 and 3. The committee gave greater emphasis to the identification of a research agenda for filling gaps in knowledge needed for sound policy decisions in this area. The committee was able only to sketch such an agenda, presented in Chapters 4 and 5, which if implemented promptly should contribute to a particularly strong 1993 report.

The committee's examination of needed research owes much to an intensive discussion of the subject that occurred during the Airlie House Conference on Research Training (Warrenton, Virginia, November 24-25, 1986), sponsored by the Institute of Medicine. The fruit of that conference was proposals for three major initiatives:

1. undertake in-depth evaluations of NIH-supported training programs;

2. develop improved measures of scientific productivity; and

3. improve the assessment of national needs for biomedical and behavioral scientists.

The first two Airlie House initiatives, training program evaluation and productivity analysis, represent an important concentration of the committee. Papers commissioned on each topic are contained in Volume III. These papers form the basis of Chapter 4, which is concerned entirely with these topics and represents an important innovation of the current report.

The topics of program evaluation and productivity analysis are linked naturally by the assumption that effective research training programs should have measurable outcomes--namely, enriching research careers and increasing the volume and quality of their output. Research with which to test this assumption in depth is recommended in Chapter 5. The committee also makes the assumption that increased financial support of graduate education, such as that for NRSA programs, yields both an increased number of graduate students and an accelerated path to the doctorate.[1]

The program evaluations recommended by the committee are intended to get at issues beyond those of effective educational enhancement. They are intended also to investigate potential negative impacts, such as the possibility that the programs reduce the quality of students available for research assistantships or that the grants may not be used to increase the number of qualified graduate students but, rather, to substitute for other money that is then used for other purposes.

The third Airlie House proposal was to extend coverage of future reports beyond the academic sector--the primary concern of earlier reports--particularly to include industry and its burgeoning biotechnology subsector. This is done in Chapters 3 and 4. The committee also examines the rapid changes in sex and race/ethnic composition of the biomedical and behavioral work force; these changes may have major implications for training programs, labor supply, and the research process itself.

The committee's counts and projections of biomedical and behavioral scientists are more comprehensive than in the past and represent an improvement over earlier projections. However, the current model is still forced to make simplifying assumptions that may be unrealistic but that are necessitated by inadequate information. For example, the current model continues the assumption that the labor market for scientists is strictly national, with no local or regional barriers. It is also assumed that any two individuals with degrees in a given field can occupy any job in that field equally well. Mobility among fields of science and into and out of science are taken into account in the models, but are assumed to occur independently of economic or other field characteristics that change over time. The committee did not devote extensive resources to an analysis of postdoctorates because this issue has been thoroughly examined in the past and because there has been very little change in the size of the postdoctoral pool in recent years. Although the current model represents a distinct improvement, its assumptions merit a closer and more critical empirical examination than was possible in the period of this study.

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[1]Empirical evidence suggests that first-year graduate enrollments are positively associated with total student support and starting wages and negatively associated with total elapsed time to degree. See Joe G. Baker, "The Ph.D. Supply Crisis: .. Look at the Biomedical Sciences," paper given at the Western Economics Association Meeting, Lake Tahoe, Nevada, June 1989 The influence of student aid on time to degree is examined in Howard Tuckman, et al., *On Time to the Doctorate*, forthcoming from the National Research Council.

Nevertheless, these labor market descriptions and projections have convinced the committee that there is need for changes in the level of support in biomedical graduate education The projections played a weaker role than previously in determining the level of support that the committee finally recommended. In prior reports, recommended levels of support were fairly direct outputs of the models used, but in this report the recommendations are products of the collective judgment of the committee, taking the projections into account. For future committees, the recommended program evaluations and related research should prove to be powerful supplements to the output of projection models.

None of this should be taken to suggest that the previous committee ignored any of the topics that we consider here. For example, the 1981 report contained a chapter on the race/ethnic composition of the biomedical and behavioral work force, but sex was not included. Both the 1983 and 1985 reports described ground-breaking surveys of scientific employment in biotechnology firms. Instead, we believe that we have an evolving perspective with a substantially greater emphasis on vital issues that determine the quality of the biomedical and behavioral scientific work force.

FINDINGS

Under the terms of the NRSA Act and its directive to NIH, the committee was asked to address several implicit or explicit research questions. The following summary of this report is couched in the form of responses to seven questions.

1. **What are the kinds, extent, and length of existing research training mechanisms in biomedical and behavioral science?**

   There exists no complete inventory of the nation's training mechanisms for biomedical and behavioral science. However, it is clear that they operate within graduate and medical school and consist mainly of traditional Ph.D. and M.D. programs, with many special programs funded by external sources.

   The major individual training mechanism is NIH, which awarded $236.8 million in NRSA training funds in 1987. In addition to NIH, the Alcohol, Drug Abuse and Mental Health Administration (ADAMHA) awarded $23.5 million, and the Health Research Services Administration (HRSA) awarded $1.2 million in NRSA training funds in 1987. These funds support a large array of training mechanisms, including limited baccalaureate training, predoctoral and postdoctoral institutional grants and fellowships, and career development programs for senior scientists. A historical summary of NRSA support appears in Table 1, page 7.

2. **How do existing training mechanisms compare in efficiency?**

   Previous studies of NRSA research training found that program participants performed better than nonparticipants in their subsequent research careers. The design of these studies makes it impossible to determine whether the differences are effects of the training programs or of the selection process. Data and methodological improvements are needed for a true evaluation of the efficiency of NRSA training programs Even in the absence of systematic data, however, the committee acknowledges inefficiencies in some training programs. In particular, committee members affiliated with medical schools believe that the program of study in M.D. research training programs is deficient in basic scientific content.

3. **What is the current state of the labor market for biomedical and behavioral scientists?**

Biomedical scientists: Demand (job openings) has been growing relative to supply (new Ph.D.s) since the early 1980s. Industrial employment growth is over twice the rate of academic employment growth. The proportion of employed biomedical scientists whose work involves primarily research and development (R&D) has increased.

Clinical psychologists: Total employment of clinical psychologists has been growing rapidly in the 1980s. The supply of new Ph.D. clinical psychologists has not kept pace with this demand. However, only a very small (and declining) proportion of employment is R&D-related; because of this, the committee gives very little consideration to this field.

Nonclinical psychologists: The labor market for nonclinical psychologists in the 1980s has been in approximate balance. Employment of nonclinical psychologists is dominated by the academic sector, which has had sluggish demand as a result of falling enrollments. A substantial number of nonclinical psychology Ph.D.s have switched fields to work as clinical psychologists, although this number should dec e as state certification requirements increase. The portion of nonclinical psychologists who are involved in R&D work has been fairly stable at about 30 percent of total employment.

Other behavioral scientists: The labor market for other behavioral scientists (anthropologists, sociologists, audiologists, and speech pathologists) has been fairly stable in the 1980s; declines in annual job openings have been matched by declines in Ph.D. production. Over 80 percent of these scientists are employed at colleges and universities, where employment growth has averaged 4.2 percent annually. The portion of other behavioral scientists involved in R&D has remained constant at approximately 19 percent.

Clinical investigators: The number of NIH traineeships/fellowships for post-professional research training of M.D.s has not increased as fast as health-related R&D expenditures. The percentage of M.D.s who are principal investigators (PIs) on NIH research grants has fallen, although the number of M.D. PIs has remained constant for the last decade at between 1,700 and 2,000.

4. **What is the expected future labor market for biomedical and behavioral scientists?**

Biomedical scientists: Most new positions in biomedical science are expected to be in industry. Unless demand growth falls considerably from historical levels and/or enrollments and degree production increase dramatically, there is projected to be an undersupply of biomedical Ph.D.s into the next century. The undersupply is expected to be even greater in the R&D segment.

Clinical psychologists: An undersupply of new Ph.D.s in clinical psychology is expected unless growth moderates considerably or degrees and enrollments increase. However, most of this projected growth will be for counseling; future demand for R&D clinical psychologists will be extremely small.

Nonclinical psychologists: The projected labor market for nonclinical psychologists is characterized by approximate balance between supply and demand. However, the strong market for clinical psychologists could draw off labor supply from the nonclinical sector.

Other behavioral scientists: The labor market for other behavioral scientists is projected to be characterized by supply and demand balance through the year 2000. In the R&D sector, demand growth is projected to exceed supply growth by a modest margin.

Clinical investigators: For all physicians, growth in supply is expected to exceed that of demand by a large margin through the year 2000. For physician/scientists, however, demand may continue to increase as national health R&D expenditures increase.

5. **What is the current state and expected future state of the labor market in the biotechnology industry?**

Based on the results of our survey of biotechnology firms (see Appendix A), more firms are having problems hiring scientists this year than last year. Over one-third reported having labor shortages (vacancies for over 90 days) in the last year. Over 80 percent of biotechnology firms plan to maintain or increase current levels of hiring, particularly those with postdoctoral training.

6. **What are the numbers and conditions of women and minorities seeking careers in biomedical and behavioral sciences?**

Females have made tremendous strides in the biomedical and behavioral work force in terms of levels of predoctoral support, Ph.D. degrees received, and postdoctoral appointments. However, the labor force particpation of females in full-time science continues to lag behind males.

The number of minority scientists, on the other hand, has experienced very little change in status in recent years and continues to lag behind by almost every measurement of participation in science. Given the strong commitment of NIH and ADAMHA to increase the numbers of minority scientists, of particular concern was the finding that minorities are underrepresented in predoctoral support by NIH. Reasons for this underrepresentation are unclear.

7. **What data resources need to be maintained or established to carry out the necessary analyses for this study?**

Several data sets have been essential to the conduct of this study, including the following: Survey of Earned Doctorates (SED); Survey of Doctorate Recipients (SDR); Information for Management, Planning, Analysis and Coordination (IMPAC); the Trainee Fellow File (TFF); and Consolidated Grant Application File (CGAF).[2] As vital as they are to the work of this committee, however, they are flawed in a number of ways. More important than the flaws is their incompleteness. Only the SDR provides career outcome measures, for example, and the sample size of the SDR is too small to permit accurate inferences about outcomes of particular sets of trainees. The committee has proposed a continuing program evaluation data matrix that would provide more adequate information.

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[2]The SED is a continuing survey of doctoral candidates administered by the graduate schools at the time of completion of all requirements for the doctoral degree. The SDR is a biennial sample survey of doctoral scientists that focuses on many aspects of the career. The IMPAC and CGA files are maintained by NIH, the former concerned with research grant and training programs and that NIH/ADAMHA administers and the latter with research grant applicants.

RECOMMENDATIONS

NRSA Support Levels

The committee's recommendations for levels of NRSA training support are summarized in Table 1.

- o *Biomedical sciences*: The committee projects that growth in demand will exceed that in supply through the year 2000. The committee recommends that the level of predoctoral support be 5,200 full-time equivalent positions (FTEPs), up from the current level of 3,681. To shorten the time to degree and to reduce graduate student attrition, the committee suggests that NIH examine the potential effectiveness of a support program tailored specifically for student support during the thesis-writing stage. The committee also recommends that postdoctoral support be increased gradually as degree production increases.

- o *Behavioral sciences*: The committee projects that the labor market for behavioral scientists will be fairly stable. The committee recommends that the level of behavioral science predoctoral and postdoctoral support be kept at their current levels of approximately 500 and 420 FTEPs, respectively. Given the low level of research involvement by clinical psychologists, the committee recommends moving support away from clinical psychology and towards nonclinical psychology and other behavioral sciences.

- o *Clinical sciences*: The committee expects that the demand for physician/scientists will increase in the future as health-related R&D increases, but in the absence of compelling data, this is speculative. Given the lack of data about supply/demand and questions about the effectiveness of physician research training, the committee recommends that the number of trainee and fellow positions for M.D. investigator training remain essentially the same until current training programs are evaluated.

- o *Health services research*: This interdisciplinary activity requires individuals trained in a variety of fields, including not only medicine but also economics, public health, sociology, statistics, psychology, and other natural and social sciences. Given the potential for increased demand for scholars in health services research, the committee recommends that research training for biomedical, behavioral, and M.D. scientists in this field be increased. The current funding mechanism for NRSA health services research training allocates one-half of 1 percent of NIH's NRSA budget to HRSA for research training.

In order to support the recommended increases in NRSA research training, the 1987 NIH/ADAMHA/HRSA training budget of over $262.2 million would have to be increased to approximately $282 million in 1990 and grow at approximately $10 million per year to a 1993 total of $312 million.[3] This represents a real growth rate of approximately 3.5 percent per year.

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[3]These budget estimates are based on an average cost per trainee of $24,851 and fellow of $25,920. These averages were computed using budget data from the *NIH Data Book 1988*, Table 16, and the "ADAMHA NRSA Training Tables 1987," Table 1. Trainee/fellow data are from Table I.1.

Table 1. Committee Recommendations for NRSA Full-Time Equivalent Training Positions, 1989-1995, and Actual Full-Time Equivalent Training Positions, 1985-1987

	Actual			Recommended						
	1985	1986	1987	1989	1990	1991	1992	1993	1994	1995
Biomedical	7741	7807	7387	7800	8200	8600	9000	9400	9400	9400
Predoctoral	4008	3856	3681	4000	4300	4600	4900	5200	5200	5200
Fellow	92	93	86	100	100	100	100	100	100	100
Trainee	3916	3762	3594	3900	4200	4500	4800	5100	5100	5100
Postdoctoral	3733	3952	3707	3800	3930	4000	4100	4200	4200	4200
Fellow	1628	1817	1580	1600	1650	1700	1750	1800	1800	1800
Trainee	2106	2135	2127	2200	2250	2300	2350	2400	2400	2400
Behavioral	971	962	924	920	920	920	920	920	920	920
Predoctoral	530	513	504	500	500	500	500	500	500	500
Fellow	40	33	37	40	40	40	40	40	40	40
Trainee	490	482	467	460	460	460	460	460	460	460
Postdoctoral	441	447	420	420	420	420	420	420	420	420
Fellow	91	91	95	100	100	100	100	100	100	100
Trainee	350	356	324	320	320	320	320	320	320	320
Clinical	2195	2229	2157	2150	2150	2150	2150	2150	2150	2150
Predoctoral	632	687	654	650	650	650	650	650	650	650
Fellow	2	6	17	10	10	10	10	10	10	10
Trainee	630	681	637	640	640	640	640	640	640	640
MSTP	629	661	636	640	640	640	640	640	640	640
Other	1	20	1	0	0	0	0	0	0	0
Postdoctoral	1563	1542	1503	1500	1500	1500	1500	1500	1500	1500
Fellow	181	139	113	110	110	110	110	110	110	110
Trainee	1382	1403	1390	1390	1390	1390	1390	1390	1390	1390
Total	10907	10998	10468	10870	11270	11670	12070	12470	12470	12470
Predoctoral	5171	5058	4839	5150	5450	5750	6050	6350	6350	6350
Fellow	135	132	141	150	150	150	150	150	150	150
Trainee	5036	4925	4698	5000	5300	5600	5900	6200	6200	6200
Postdoctoral	5737	5941	5629	5720	5820	5920	6020	6120	6120	6120
Fellow	1899	2047	1788	1810	1860	1910	1960	2010	2010	2010
Trainee	3838	3894	3841	3910	3960	4010	4060	4110	4110	4110
HRSA (not include in above figures)	NA	NA	NA	77	79	81	83	85	85	85

NOTE: Totals may not add due to rounding. All figures are in full-time equvilalent trainee/fellow years. Actual appointments in 1987 were 12,041 (10,815 NIH and 1,226 ADAMHA). Appointments exceed FTE trainee/fellow years (10,468 in 1987) because of partial-year appointments. Does not include short-term training positions.

SOURCE: Historical data are from Table 1-5.

Needed Research

- *Program of study for physician/scientist training*: This committee recommends that a conference, committee, or study be implemented to examine the program of study for physician/scientist training supported by postdoctoral institutional training grants. This investigation should focus on the potential merits of including more exposure to basic science and scientists in these training programs.

- *Studies of recruitment and retention*: We need far more comprehensive knowledge than we have concerning factors that facilitate recruitment and retention of able students at all stages of education leading to careers in science. These studies should emphasize the recruitment and retention of women and minorities.

- *Survey studies of former trainees with control groups*: This should be a first step in evaluating the relative efficiency of NIH training mechanisms. Study populations should consist of cohorts of entrants to graduate school rather than Ph.D. recipients. The committee recommends that the first two programs to be evaluated in this fashion be the Minority Access to Research Careers (MARC) and the Medical Scientist Training Program (MSTP).

- *Studies of women and minorities*: The academic pipeline for women is coming more and more to resemble that for men in biomedical and behavioral sciences. Evidently, NIH and other training programs are working effectively, at least in terms of their recruitment and retention through the doctorate. However, once into the career, the professional behavior of women and men continues to differ in important regards, such as numbers of papers published and citations received. The committee suspects, but lacks data with which to show, that some of these differences result from different experiences in graduate school. The committee lacks the evidence on which to base concrete recommendations in this regard, but does suggest a program of research that is intended to provide specific guidelines.

  In the case of targeted minorities, recruitment and retention into careers in biomedical and behavioral science remain worse than for whites. Little is known about the careers of minority scientists; we can only assume them to resemble those of women more than those of white males. Again, the committee lacks data with which to make concrete recommendations for intervention and can only recommend research designed to provide them. NIH has several important recruitment programs, such as Minority Access to Research Careers, but measurable changes in numbers of targeted minorities are not yet being seen. Although there are several potential causes of this lack of minority progress in biomedical and behavioral science, this could suggest that these programs are ineffective. The program evaluations proposed by the committee will make this determination possible.

- *Improvements in data and information*: The committee also recommends a number of specific improvements in the data sets needed to support more rig ous future analyses.

Other Recommendations

- *Interdisciplinary programs*: To meet changing national priorities, the committee urges NIH to continue to evolve its pre- and postdoctoral

programs, and we support the need for some of these programs to be interdisciplinary in nature (e.g., health services research).

- *Needed organization with which to implement these recommendations*: Given the research and evaluation agenda detailed in this report, the committee recommends that a new committee be activated no later than January 1992 in order to allow two years for the preparation of the 1993 report.

CHAPTER 1

THE ROLE OF NRSA PROGRAMS IN THE EDUCATION PIPELINE

OVERVIEW

The "pipeline" to a career in the biomedical and behavioral sciences starts early, and each stage is dependent on the stage before it. Unfortunately, it is far easier to leave the pipeline than to get into it at a later stage. As a result, there are fewer and fewer young people at each successive stage. The pipeline leaks.

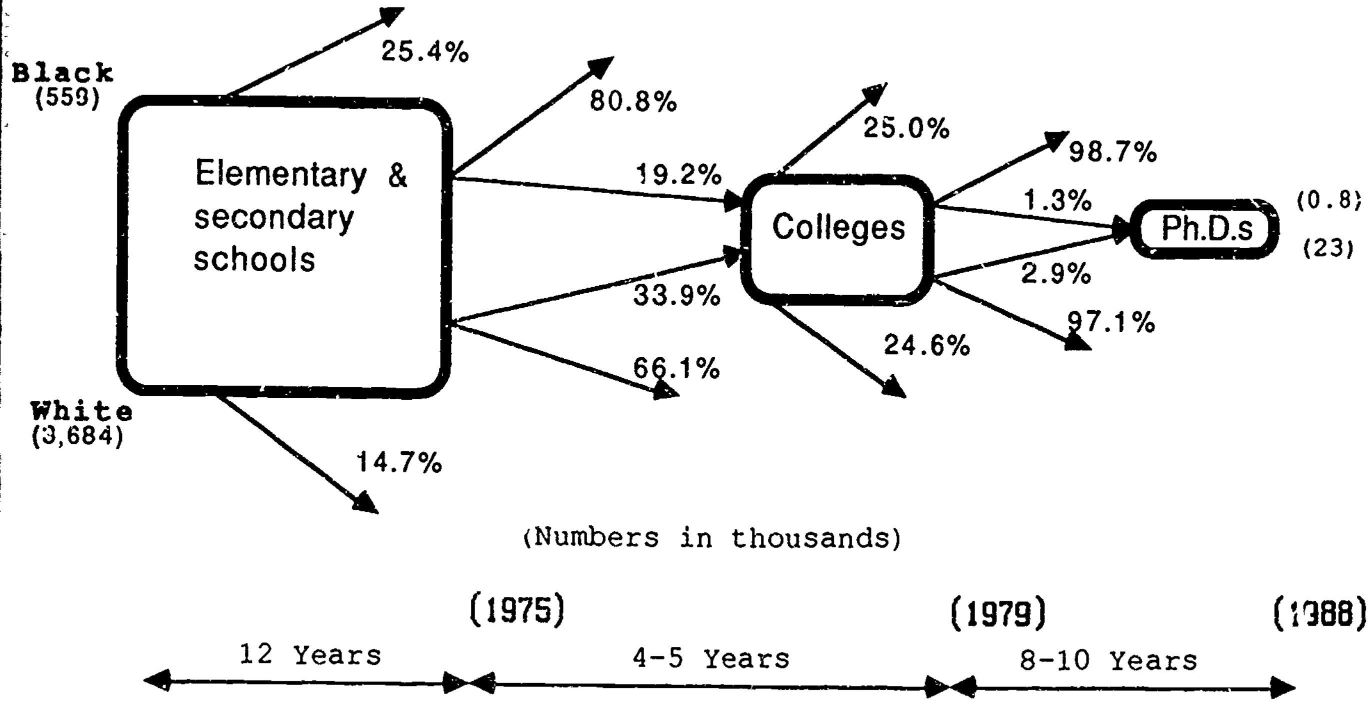
The National Research Service Act (NRSA) supports a number of programs that are designed to maintain an adequate supply of biomedical and behavioral personnel, with the quality and skills needed to support increasingly sophisticated biomedical research. The effectiveness of the NRSA programs, which are primarily aimed at postbaccalaureate training, is constrained by the level and quality of students at that stage in the pipeline. The most important of these programs are *training grants*, given to institutions, and *fellowships*, awarded to individuals. A smaller number of non-NRSA career award grants provide clinical research support and experience for young physician/scientists and others.

The total number of NRSA training positions supported by NIH and ADAMHA has remained steady, at between 10,000 and 11,000 per year, since 1978. Trends within that total, however, show that support has been shifting from predoctoral to postdoctoral training. Biomedical sciences dominate these programs, with 70 percent of all positions in 1987, equally distributed between pre- and postdoctoral. In the behavioral sciences, support for predoctoral positions has declined since 1982 but still outweighs that for postdoctoral positions. Clinical sciences received only 20 percent of NRSA support in 1987, with most of it going to postdoctoral positions.

THE EDUCATION/EMPLOYMENT PIPELINE

The charge of this committee requires it to examine the United States' work force of biomedical and behavioral scientists not merely as sets of numbers, but also as human beings, some of whom have extremely productive careers, others who have less so, and still others who drop out altogether. To gain some understanding of this variability--and to determine whether the many millions of dollars that NIH/ADAMHA annually invests in the training of scientists makes any difference--it is necessary to think longitudinally about scientists' training and careers.

All education systems can be considered in terms of a conceptual pipeline that students enter after meeting certain requirements and through which they pass from one stage to the next based on individual preferences, abilities, and responses to institutional circumstances and public policies. The pipeline leading to Ph.D. and M.D. degrees and entry into the scientific work force can be thought of as a series of interconnected pools. Figure 1-1 shows the rates of recruitment, retention, and graduation for white and black students as they progress from elementary and high school, to undergraduate college, graduate and professional schools (medical, dental, etc.), and finally to the receipt of doctorates. This figure demonstrates the length of the process that produces a qualified



SOURCE: Appendix Table A-5.

Figure 1-1. The academic pipeline for persons ever attending U.S. elementary and secondary schools, by race, 1975 to 1988.

scientific work force--at least 23 years, including elementary and secondary schools.[1] It follows from the extreme length of this process that:

1. the market-ready scientists of the year 2000 are now college sophomores; and

2. early intervention is required to change significantly the flow of individuals to specific science programs.[2]

Three basic forces determine the movement of students into and through the pipeline into science:

o *Readiness*: At every level of the pipeline, readiness to move ahead is determined by the individual's capacity to construct, transmit, and receive ideas that are formulated mathematically. Mastery of an appropriate level of mathematics is necessary, but clearly not sufficient, to entering and remaining in the pipeline.[3] Increasingly, a detailed knowledge of the substance and methods of science is also a necessary characteristic of readiness. In addition, readiness of an individual is influenced by a large set of factors, chief among them probably being one's innate ability and family values regarding education and knowledge.

o *Recruitment*: Given that one is ready to enter the pipeline to science, whether one actually does so is the result of a complex set of circumstances. While family values concerning the worth of science are critical in reaching the decision to pursue a scientific career, the quality of precollege science and mathematics instruction is equally important to the recruitment of capable students into the science pipeline. Some studies have indicated that the decision to enter the science pipeline is made in high school or even earlier, but that "by college graduation only 35 percent of the high school seniors who planned mathematics, science, or engineering (MSE) majors have stayed with their plans."[4] These losses may be important, but it may also be unreasonable to expect binding career commitments by the final year of high school.

o *Retention*: It is probably fruitless to examine retention in the science pipeline earlier than the junior year of college, when majors usually are declared. By that time, in addition to family, peer, faculty, and other significant influences, another factor taking on great significance is the availability of financial support. Money serves both as a barrier to acquiring the advanced

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[1]Indeed, in the cases of those whose education includes obtaining M.D. and Ph.D. degrees and a substantial period of postdoctoral study, the time from entry into the school system to entry into the work force can be as long as 30 years. It should be noted, however, that during the last 10-12 years, such students are contributors to the nation's research productivity.

[2]For instance, only those college students who have obtained mathematics and quantitative science credits in high school can opt for scientific careers.

[3]See P. R. Rever, *Scientific and Technical Careers: Factors Influencing Developing During the Educational Years*, Iowa City: The American College Testing Program, 1973.

[4]Government-University-Industry Research Roundtable, *Nurturing Science and Engineering Talent: A Discussion Paper*, Washington, D.C.: National Academy Press, 1987, p. 29.

training needed for a scientific career and as a force motivating one to drop out of the pipeline in favor of more lucrative alternatives. As Figure 1-2 makes clear, retention rates are so poor in biomedical and behavioral graduate programs that there is a potential for significant improvements, with consequent increases in the numbers of new doctoral scientists each year.

It is clear that many factors influence the size of the cohorts in each pool of the education/employment pipeline. Decisions made by individuals are combinations of personal, financial, and contextual elements--influenced by the behavior of individuals, the advice and guidance of counselors and mentors, and individual perceptions of the status of a scientific career and national priorities. Assessments of how to influence the flow of individuals through this system must take into account such factors.

A high school graduate may choose to enter the work force immediately, enroll in a junior college before entering a four-year university, or matriculate at a university directly from high school. But the availability of these options is altogether contingent on the level of readiness. Only with adequate mathematics and science preparation in high school does the student have the option to enter college science programs that can lead to subsequent graduate or professional school work. Inadequate science and mathematics performance in middle school frequently reduces the options and shunts the high school student to a noncollege program or to a delay of college entry for remedial work. This path is particularly common for minority students, who frequently lack crucial information and institutional attention early in their careers.

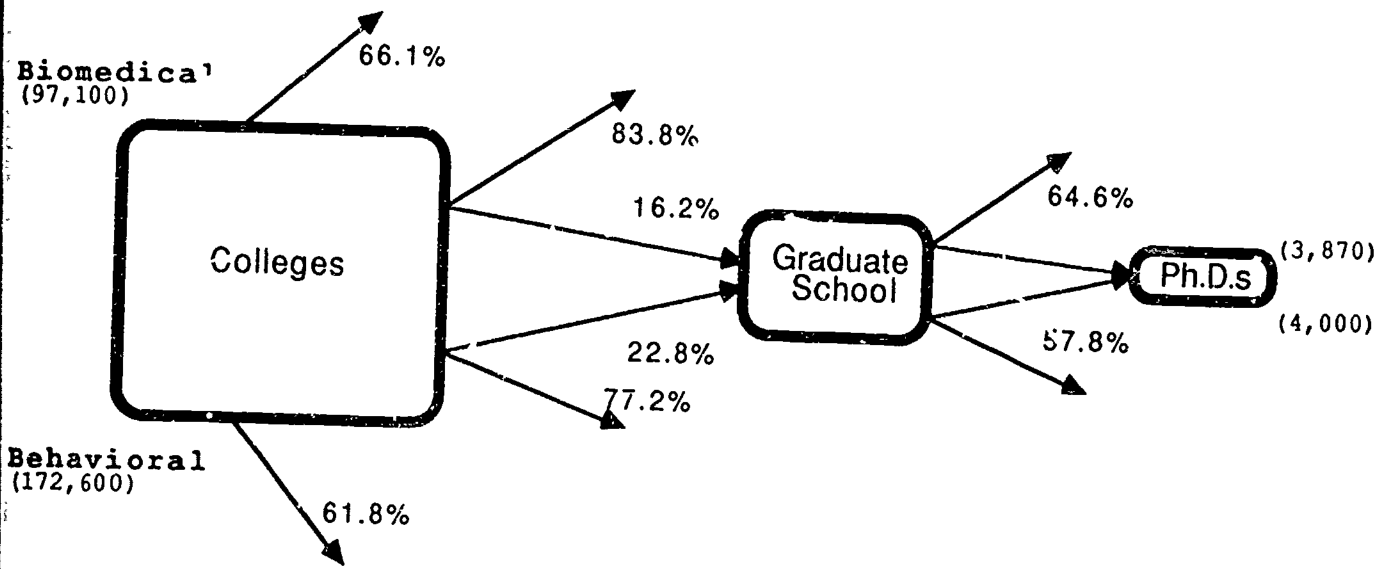
The Pipeline into the Basic Biomedical Sciences

Entry into college is the point at which the data permit us to focus on the fields of concern here. Figure 1-2 shows the current pipeline from the point of college matriculation. This figure again emphasizes the fact that the pipeline is extremely "leaky." The number of B.A./B.S. degrees in biomedical science is much less than the number of freshmen who four years earlier expressed the intention of earning such a degree. Far more of the leakage is into other fields, especially those that are business-related, than out of college. The number of baccalaureate degrees with majors in the biological sciences rose steadily to a peak of 52,000 in 1976 but then declined until 1984, when a new upward trend began. Currently, about 37,000 bachelor's degrees in the biological sciences are awarded annually by U.S. institutions (see Volume II of this report, Table 2).

At the next stage of the pipeline, entry into graduate or professional school, individual preferences and responses to environmental factors greatly influence the decision to pursue and complete a graduate or professional program and to enter a career in science. Students completing graduate programs, as well as a small proportion of those completing the M.D. or another professional biomedical program, can move directly into the work force,[5] choosing careers in academe, industry, or government.[6] Others opt forpostdoctoral training, a percentage that approximately doubled between 1972 and 1982

[5]Those pursuing a career in basic research would probably undertake postdoctoral training first. A relatively small proportion of those completing graduate programs move to professional training.

[6]The length of time spent in research careers is highly variable, but attrition rates from the work force have been relatively low--amounting to 2-3 percent per year in biomedical science and not quite 5 percent in behavioral fields. Because the average age of the work force has increased steadily, however, attrition rates are projected to increase within the next decade.



SOURCE: Appendix Table A-6.

Figure 1-2. The academic pipeline for biomedical and behavioral sciences, selected years.

but has since remained level. About 8,200 individuals currently are engaged in postdoctoral training in the biomedical sciences.

The professional and graduate biomedical degree programs have significantly different attrition rates: whereas attrition from professional programs seems relatively minor,[7] that from graduate programs appears to be as high as 58 percent.[8] High attrition rates may be influenced by the length of postdoctoral training and/or the availability of federal funds in the biomedical sciences. The data may also be unintentionally misleading --some proportion of the first-year graduate students may successfully attain the terminal master's degree that they had intended and thus blur the comparison between first-year graduate students and doctorate recipients eight years later. Even if this proportion were large, however, the amount of leakage during graduate school would remain high enough to merit careful analysis.

The steadily increasing size of the pool of postdoctoral biomedical scientists has raised concern for many years.[9] However, funds to support postdoctoral training come largely from federal grants, contracts, and fellowships. The size of the pool therefore reflects directly the national priority for biomedical research: the postdoctoral pool, as well as the graduate pool, is a major contributor to the research programs of granting agencies. The ways in which federal support is provided, the criteria used to evaluate programs, and the success of individual participants are discussed in Chapter 4.

Finally, annual attrition from the biomedical science work force (due to death and retirement) has been approximately 1,200 recently and is expected to increase to nearly 1,700 within the next decade. Recognizing this, as well as the fact that only approximately 1.1 percent of individuals with doctorates in the biomedical sciences are unemployed, the committee stresses that the present production rates are inadequate to meet current national needs.

The Pipeline into Behavioral Sciences

Figure 1-2 also illustrates pool sizes and leakages from the pipeline into the behavioral sciences following high school. In some respects, the picture is similar to that for the biomedical sciences, but more extreme. The initial numbers of freshmen expressing interest in majoring in a behavioral science are considerably greater than for biomedical fields, but their retention rate is much lower. The differential attrition continues until the point of awarding doctorates, by which time the initially large numeric difference between the two fields has become trivial. At this point, furthermore, a substantial fraction of new biomedical Ph.D.s go on to a period of postdoctoral training. Very few behavioral

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[7]Exact numbers are not available.

[8]The numbers used in Figure 1-2 are taken from Appendix Table 3-1 in Volume II of this report and are averages over several years. The attrition rate may in fact be due in part to a lengthening of the time spent in graduate study. Nonetheless, even if this is taken into account, the attrition rate for biomedical scientists is very high and points to the possibility that either selection processes or retention efforts could be improved in order to enhance the efficiency of the system and to increase productivity.

[9]Very little information is available about the extent to which trainees leave the postdoctoral training pool to pursue different careers in or out of science. The imbalance between inputs and outputs cannot be taken as projecting the growth rate of the pool, since to some extent the discrepancies reflect the varying quality of information available for analysis.

scientists do postdoctoral work, and their numbers are not increasing materially, despite the recommendations of earlier committees.

THE STRUCTURE OF NRSA TRAINING PROGRAMS

The National Research Service Act (NRSA) supports a great variety of training activities, all fields of biomedical and behavioral sciences, as well as interdisciplinary programs related to specific disease problems and health services research. This training is available at many points in the education pipeline: to some undergraduate students. graduate students studying for their Ph.D.s, postdoctoral students, and persons who have already received an M.D. or other professional degree. In addition, the Medical Scientist Training Program (MSTP) supports courses of study leading to a combined M.D./Ph.D. degree. The Minority Access to Research Careers (MARC) program is designed to increase minority participation in research.

Training grants and fellowships are the principal vehicles used by public agencies to influence the production of Ph.D. and M.D. biomedical and behavioral scientists. Almost all of the institutes at NIH/ADAMHA support training through one or both vehicles, each program having been created in response to a perceived national need. Awards are made on the basis of national competition and the responsiveness of proposals to criteria established by the granting agency.

The overall goals of these biomedical and behavioral training programs are threefold:

1. to provide for a *supply* of personnel sufficient to meet demand;
2. to ensure that their *quality* is high enough to carry on increasingly sophisticated biomedical and behavioral research; and
3. to make sure that the pool of *skills* responds to shifts in demand for various kinds of specialized personnel.

To reach these goals, a number of mechanisms are employed, the adoption of which is based on assumptions (explicit or implicit) concerning how occupational choices are made, how biomedical and behavioral research skills are acquired, and what the market will be for personnel having such skills. (Chapter 4 provides an extended discussion of the goals, mechanisms, and outcomes of these training programs.) The two major activities supported by NRSA are training grants and fellowships.

Training Grants

Institutional training grants are awarded to academic departments and programs rather than to individuals. The peer review groups examine the training plan, but the trainees are selected by the training institution. While each training grant award can be perceived to be unique, major differences exist between those provided to support graduate education and training and those supporting postdoctoral education.

Predoctoral Training Grants: Covering tuition and a small factor of support to the training group, these grants are awarded mainly by the National Institute of General Medical Sciences (NIGMS) in a number of interdisciplinary and disciplinary fields, based on an intensive review of the quality of the existing academic graduate program of the

applicant department and institution.[10] The size of the applicant pool and the field of students accepting admissions are taken into account. The purpose of predoctoral training grants is to increase the capacity of a preexisting program to train biomedical or behavioral scientists.

The success of the program is judged by peer reviewers, using such measures as diversity of course offerings, quality of the instructional group, academic standards of the group, flexibility in terms of the development of dissertation projects, time required for students to obtain a degree, success of students in accomplishing high-quality research, and the success of former students in obtaining either postdoctoral appointments in leading laboratories or first independent appointments in research universities and institutions. Reviewers also make judgments about commitment of financial and other support to the academic effort, and they usually attempt to ensure that a training grant will increase the number of trainees to the program. In some cases the award of training grants is used to leverage additional institutional support for the program.

Postdoctoral Training Grants: Training grant awards for postdoctorates tend to focus more directly on research experience. Criteria similar to those for predoctoral grants are used in making postdoctoral awards in the basic biomedical and behavioral areas, although they are less commonly applied to clinical science training awards (see below). In every case, however, careful judgments are made about the quality of the training staff and their research productivity. Training grant programs account for about 76 percent of NRSA training positions funded through NIH/ADAMHA.

Fellowships

Awarded on an individual basis--mostly to postdoctorates who, together with a specific research sponsor, proposed a research project to be pursued if an award is made--fellowships are given in response to the research accomplishments of the fellow and the mentor. Most fellows seeking postdoctoral awards have already had successful careers as graduate students and can demonstrate a capacity for original research; that, together with the quality of the proposed project, determines success in obtaining the award. In a sense, research fellowship awards are small research grants, but they provide recognition and support for outstanding young scientists at an early point in their careers.[11] Fellowships account for 17 percent of NRSA-supported positions funded through NIH/ADAMHA.

NRSA Training for Physician/Scientists

Fifty years ago, a physician/scientist was an individual engaged in research at the bedside or in the clinic, observing cause and effect in the human model: a substance given or withheld, and a result measured. The past several decades, however, have seen a shift in emphasis from the clinic to the biochemical laboratory, where investigations are conducted at the cellular level. For purposes of definition, therefore, the "physician/scientist"

[10]Included in the review are evaluations of mentors' success in previous training of research scientists, obtaining and sustaining research support from granting agencies, publications, citations, prizes and awards, and stature in the field. Evaluation of potential trainees is based on their grade-point averages, test scores, baccalaureate institution, and undergraduate research experience. Also assessed are physical facilities, institutional commitment, and existing financial support for the program.

[11]In addition to NRSA-supported training, NIH and ADAMHA support other programs for advanced research training. Of particular importance in this series is the Physician/Scientist Training Program which supports researchers over a five-year period, beginning at the career stage traditionally spent in postdoctoral research training.

referred to throughout this report is one who has earned the M.D. degree, has had additional training or experience in the basic sciences or held clinical fellowships, and has spent varying proportions of his or her time in both scientific investigation and clinical practice.

NRSA currently supports several types of physician/scientist training programs, including the Medical Scientist Training Programs (MSTP) leading to the M.D./Ph.D. degree, institutional training grants, and other special fellowships. Because of their formal curriculum, firmly grounded in the basic sciences, MSTP and Physician/Scientist Award Program have an assumed advantage, in terms of scientific training, over the traditional institutional training grant conducted in the subspecialty divisions of clinical departments. This superiority can only be assumed, however, because of a lack of substantive evaluations of these programs (see Chapter 4).

A STATISTICAL OVERVIEW OF NRSA TRAINING PROGRAMS

This section focuses on NRSA programs administered by NIH and by ADAMHA.[12] It describes the current size and budget of the various program components; it also provides an historical overview of NRSA training. The definition of NRSA training used here is the trainee ("T" programs) and fellowship ("F" programs) support programs for predoctoral and postdoctoral students funded under NRSA. In addition, a discussion of non-NRSA research training is included.

NRSA Training Programs in FY 1987

In FY 1987, NIH and ADAMHA supported a total of 11,242 NRSA full-time equivalent positions (FTEP).[13] These positions were divided into the following basic types of NIH and ADAMHA research training programs: predoctoral and postdoctoral traineeships, predoctoral and postdoctoral fellowships, and short-term training (Table 1-1).

Traineeships: Training grants are awarded to institutions, usually to academic departments, rather than individuals. While the grant applications by the institutions are subject to peer review, selection of both predoctoral and postdoctoral trainees is controlled by the institution receiving the grant. Programs are designated in the NIH data system by "activity codes;" all traineeship programs have an NIH activity code beginning with "T." In 1987, FTEP traineeships accounted for 76 percent of all NIH and ADAMHA training positions. The $192.1 million spent on institutional awards in 1987 represented 80 percent of the $238.8 million total awarded for research training within NIH.[14]

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[12]The Health Research Services Administration (HRSA) is the only other agency that provides NRSA support to students. In FY 1989, HRSA supported 69 trainees and 8 fellows. Data for HRSA are not included in the above analysis.

[13]Training positions are defined in terms of full-time equivalent positions (FTEP), i.e., the number of positions during the year calculated as if each trainee/fellow was employed for 12 months (three months for short-term training). The actual number of individuals supported was higher than the number of positions. FTEP data were computed from the NIH Trainee/Fellow File (TFF) by the National Research Council and differ from the number of appointments as reported in the *NIH Data Book 1988*.

[14]*NIH Data Book 1988*, Table 16.

Table 1-1. 1987 NRSA Training by Field, Agency, and Definition

Full-Time Equivalent Training Positions				Estimated Training Appointments			
BIOMEDICAL	TOTAL	NIH	ADAMHA	BIOMEDICAL	TOTAL	NIH	ADAMHA
Total	7388	7009	379	Total	8436	7961	475
Predoctoral	3681	3499	182	Predoctoral	4268	4041	228
Fellow	86	67	19	Fellow	95	71	24
Trainee	3594	3431	163	Trainee	4173	3969	204
Postdoctoral	3707	3510	197	Postdoctoral	4167	3920	247
Fellow	1580	1531	49	Fellow	1692	1631	61
Trainee	2127	1979	148	Trainee	2475	2289	185
BEHAVIORAL	TOTAL	NIH	ADAMHA	BEHAVIORAL	TOTAL	NIH	ADAMHA
Total	924	402	522	Total	1112	457	655
Predoctoral	504	250	254	Predoctor.	604	285	319
Fellow	37	35	2	Fellow	40	37	3
Trainee	467	214	253	Trainee	564	248	317
Postdoctoral	420	152	268	Postdoctoral	508	172	336
Fellow	95	25	70	Fellow	114	27	88
Trainee	324	126	198	Trainee	394	146	248
CLINICAL	TOTAL	NIH	ADAMHA	CLINICAL	TOTAL	NIH	ADAMHA
Total	2157	2080	77	Total	2493	2397	96
Predoctoral	654	638	16	Predoctoral	758	738	20
Fellow	17	1	16	Fellow	21	1	20
Trainee	637	637	0	Trainee	737	737	0
Postdoctoral	1503	1442	61	Postdoctoral	1735	1659	76
Fellow	113	102	11	Fellow	122	109	14
Trainee	1390	1340	50	Trainee	1613	1550	63
TOTAL	TOTAL	NIH	ADAMHA	TOTAL	TOTAL	NIH	ADAMHA
Total	10469	9491	978	Total	12041	10815	1226
Predoctoral	4839	4387	452	Predoctoral	5631	5063	567
Fellow	140	103	37	Fellow	156	110	46
Trainee	4698	4282	416	Trainee	5475	4954	521
Postdoctoral	5630	5104	526	Postdoctoral	6410	5752	659
Fellow	1788	1658	130	Fellow	1929	1766	163
Trainee	3841	3445	396	Trainee	4481	3985	496
T35 Short-Term Training (not included in above figures)							
Total	774	752	22		774	752	22
Grand Total	11243	11243	1000		12815	11567	1248

NOTE: Totals may not add due to rounding. Full-time equivalent estimates are in term of trainee/fellow years, i.e., one trainee/fellow for 12 months. Actual appointments are higher due to partial year awards. Appointments are consistent with reported training figures published in the <u>NIH Data Book 1988</u> and in <u>ADAMHA NRSA Research Training Tables FY 1987</u>. Field of trainee/fellows determined by degree/specialty/field data on individual trainee/fellow record (Form 2271).

SOURCE: Estimated by National Research Council from the NIH Trainee Fellow File.

Table 1-2 shows that the T32 program (institutional training grants) is the largest single training effort within NIH/ADAMHA. In 1987, there were 4,347 predoctoral and 3,824 postdoctoral positions in the T32 program, comprising 72.7 percent of the total NIH/ADAMHA training effort of 11,242 positions. The stated purpose of the T32 program is "to help ensure that highly trained scientific manpower will be available in adequate numbers and in the appropriate research areas and fields for the nation's biomedical and behavioral research agenda."[15] T32 trainees are required to devote at least 40 hours per week to research training and must be citizens or have permanent visas. Prior to appointment, trainees must sign a "payback" agreement, by which they agree to engage in biomedical/behavioral research and/or teaching for a period equal to the T32 support period in excess of 12 months. If trainees do not begin to carry out this requirement within two years of NRSA program termination, they are required to return the support funds to the federal government. Stipends are currently $8,500 per annum for predoctoral students and range from $17,000 to $31,500 per annum for postdoctoral students, depending upon experience. Appointments are made for 12 months; no trainee may receive more than five years of aggregate NRSA predoctoral support and three years of aggregate postdoctoral support without a special waiver. A significant subset of the T32 program is the Medical Scientist Training Program (MSTP), which provides training in biological, chemical, physical, and social sciences, combined with medical training, and leads to a joint M.D./Ph.D. degree. In FY 1987 the MSTP program was composed of 636 FTEP positions, or 14.7 percent of the total T32 predoctoral FTEPs, or 4,347.[16] All of the MSTP positions were in clinical science.

The T34 Minority Access to Research Careers (MARC) program is somewhat unusual in that it is aimed at undergraduates. MARC is one of several NIH/ADAMHA programs designed to increase the numbers and capabilities of biomedical and behavioral scientists from underrepresented minorities. In addition to student support, the T34 program provides funds for consultants, personnel, staff travel, and research equipment and supplies. The program also allows trainees to undertake special work at major research universities and laboratories during summer sessions.

The T35 program (774 positions in FY 1987) is intended for short-term training. Although it can provide support to postdoctorates, it is designed as a vehicle to introduce students in health professional schools to a research career and/or research in an area of national need. In this program trainees usually are funded for only three months during their summer term or during an off quarter.[17]

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[15]See National Institutes of Health, "National Research Service Award Grants (T32)," mimeographed supplement to be used with T32 grant application, April 1989, p. 1.

[16]In addition to the MSTP program at the National Institute of General Medical Sciences (NIGMS), the National Institute of Neurological and Communicative Disorders and Strokes (NINCDS) has designed a program under the T32 umbrella that is specifically aimed at short-term training of M.D.s. This program is thus run as a *de facto* T35 short-term training program; NINCDS feels that M.D.s who receive exposure to research through this mechanism are more likely to pursue research careers.

[17]The National Heart, Lung and Blood Institute (NHLBI) runs a Minority Hypertension program within the T35 program that is not research training in the traditional T35 sense. These positions in NHLBI, numbering 404 in 1987, have been excluded from the data presented here. ADAMHA supported 22 of the T35 positions; the remaining 752 were supported by NIH.

TABLE 1-2. NIH/ADAMHA NRSA Training Program Description (T Programs)

Activity Code	Program Description	Type	1987 Program Size (FTEP Awards) Biomedical	Behavioral	Clinical	Total	1987 Program Cost (Annualized Direct Cost per Trainee) Biomedical	Behavioral	Clinical
T15	Continuing education grants to assist professional schools and other institutions (e.g., continuation, extension, refresher education in new science in the profession)	Postdoc	10		8	18	$31,141		$32,000
T32	Institutional grants to enable institutions to award NRSA support to individuals selected by the institution; study in selected "shortage" areas	Predoc	3,265	446	636	4,347	$12,915	$11,443	$15,407
		Postdoc	2,118	324	1,382	3,824	$21,899	$21,069	$26,253
		Total	5,383	770	2,018	8,171			
T34	MARC undergraduate institutional grants to enable minority institutions to award support to individuals selected by the institution for undergraduate research in biomedical and behavioral sciences	Undergrad	329	21	1	351	$8,258	$7,654	$10,504
T35	NRSA short-term training to provide individuals with research training in summer or off quarters to encourage research careers in areas of national need	Total				774			$2,383
Total	Note: Total cost data are weighted means and exclude T35 program.	Undergrad	329	21	1	351	$8,258	$7,654	$10,504
		Predoc	3,265	446	636	4,347	$12,915	$11,443	$15,407
		Postdoc	2,118	324	1,382	3,824	$21,899	$21,069	$26,253
		Total	5,722	791	2,027	8,540	$16,003	$15,285	$22,865

NOTE: The number of trainees is calculated in terms of full-time equivalent positions (FTEP); one trainee for 12 months, rather than actual awards. Actual awards include individuals who were in the program for less than 12 months during 1987; awards are approximately 10 percent higher than trainee years. For the T35 short-term program, an FTEP was defined as one trainee for 3 months. Cost data also were normalized for a trainee-year basis (3 months for T35; 12 months for all others). These cost data (from the Trainee Fellow File (TFF)) include stipend, dependency, travel, and tuition. They exclude administrative and some other costs and should not be interpreted as an indication of the total cost of the program.

SOURCE: Calculated by National Research Council from the NIH Trainee Fellow File.

In FY 1986, Ph.D.s comprised 55.4 percent of NIH postdoctoral trainees (down from 63.6 percent in 1980); M.D.s made up the remaining 44.6 percent (up from 36.4 percent).[18]

Fellowships: Fellowships are awarded on an individual basis, primarily for postdoctoral study. They are extremely competitive and are awarded on the basis of a thorough review of proposed research with a mentor and sponsoring institution. In 1987 fellows made up 17.2 percent of all training positions, with awards allocated at a cost of $46.6 million, or 19.1 percent, of the NIH/ADAMHA research training budget. Table 1-3 provides a description of the FY 1987 NRSA fellowship programs. The F32 program is clearly the largest; in FY 1987 it supported 78.9 percent of all fellowship positions. The F32 program is designed to provide postdoctoral research training to individuals to broaden their scientific backgrounds and extend their potential for research in specified health-related areas. The F31 program is the predoctoral equivalent of the F32 program: together these two programs supported over 85 percent of NRSA fellows. In 1987, Ph.D.s comprised 85.3 percent of NIH postdoctoral fellowships, while M.D.s made up the remaining 14.7 percent.[19]

Other NIH Research Training Activities: In addition to the programs described above, several activities at NIH provide research experience.

- *Career Award Grants.*[20] These awards, made on both an individual and institutional basis, provide up to five years of support for scientists early in their careers. Designed to free recipients from teaching and administrative duties such that they can devote a major effort (at least 80 percent) to research, they are widely considered to be "super-postdoctorals." Indeed, career award grants occupy a somewhat "gray" area between research and training; most individuals who receive career award grants have already proven their ability to do independent research and have embarked upon research careers. These so-called "K" programs are an important source of research experience for promising physician/scientists: as shown in Table 1-4, awards directed toward physicians (K08 and K11) accounted for 90 percent of the total K positions in FY 1987. The K12 and K16 programs are career development institutional grants made to medical schools (K12) and dental schools (K16); the institutions then appoint clinicians for development of individual research skills. In 1987, the K12 program supported approximately 52 scientists at 12 different institutions; the K16 program supported approximately 39 scientists at nine different institutions.

- *R25 Research Grants*: The National Cancer Institute (NCI) administers a program for the training of doctoral students in cancer prevention; providing student laboratory research experience to high school, prebaccalaureate, and predoctoral students; curriculum development in nutrition/cancer prevention;

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[18]See National Institutes of Health, *NIH Data Book 1988*, Washington, D.C.: National Institutes of Health, 1988, Table 39. Degree of postdoctoral trainee data are unavailable from ADAMHA.

[19]*Ibid.* Degree data for ADAMHA fellows are unavailable.

[20]It should be noted that the K programs do not fall under the NRSA program umbrella and are not funded from research training funds.

Table 1-3. NIH/ADAMHA NRSA Fellowship Program Description (F Programs)

Activity Code	Program Description	Type	1987 Program Size (FTEP Awards) Biomedical	Behavioral	Clinical	Total	1987 Program Cost (Annualized Direct Cost per Fellow) Biomedical	Behavioral	Clinical
F05 F06 F15	International Fellowships. For collaborative research for alien scientists (F05), senior international fellows for U.S.medical school faculty to study abroad (F06), and Fogarty International fellows who spend 3 to 12 months in residence at NIH (F15)	Predoc	2			2	$28,895	$27,994	
		Postdoc	153	5		158	$24,108	$25,307	
		Total	155	5		160			
F31	Predoctoral NRSA fellows for specified research leading to research degree	Predoc	73	37	16	126	$12,402	$10,652	$8,772
		Postdoc	0	0	0	0			
		Total	73	37	16	126			
F32	Postdoctoral NRSA fellows for specified research to broaden research background and extend research potential	Predoc	0	0	0	0			
		Postdoc	1,347	83	94	1,524	$22,631	$20,922	$27,764
		Total	1,347	83	94	1,524			
F33	NRSA senior fellow awards to provide opportunities for senior scientists to make major changes in careers, e.g., new research training, learning new fields, sabbaticals	Postdoc	22		2	24	$32,637		$33,000
F34	MARC Faculty awards. Fellowships to minority institution faculty for advanced research training	Predoc	10			10	$18,955		
		Postdoc	14	1		15	$25,593	$35,000	
		total	24	1		25			
F35	Intramural NRSA awards. Support for research training in the NIH intramural program	Predoc	2		1	3	$12,808		$32,000
		Postdoc	45	7	17	69	$18,511	$14,430	$14,800
		Total	47	7	18	72			
Total	Note: total cost data are weighted means	Predoc	87	37	17	141	$13,544	$10,652	$10,138
		Postdoc	1,581	96	113	1,790	$22,822	$20,824	$25,906
		Total	1,668	133	130	1,931	$22,338	$17,994	$23,844

NOTE: The number of trainees is calculated in terms of full-time equivalent positions (FTEP); one trainee for 12 months, rather than actual awards. Actual awards include individuals who were in the program for less than 12 months during 1987; awards are approximately 10 percent higher than fellow years. Cost data also were normalized for an FTEP basis. These cost data (from the Trainee Fellow File (TFF)) include stipend, dependency, travel, and tuition. They exclude administrative and some other costs and should not be interpreted as an indication of the total cost of the program.

SOURCE: Calculated by National Research Council from the NIH Trainee Fellow File.

TABLE 1-4. NIH/ADAMHA Career Development Program Description (K Programs)

Activity Code	Program Description	Type	1987 Program Size (FTEP Awards) Biomedical	Behavioral	Clinical	Total	1987 Program Cost (Annualized Direct Cost per Trainee) Biomedical	Behavioral	Clinical
K01 K02	Research Scientist Development Award. Supports scientists already committed to research for additional training and research experience	Postdoc	13	5	14	32	$55,718	$56,154	$69,923
K05	Research Scientist Award (ADAMHA). Support of a senior scientist in research of his/her sponsoring institution	Postdoc	8	9	1	18	$59,517	$59,328	$66,317
K06	Research Career Award enables institutions to fund positions favorable for intellectual growth of investigators of high competence	Postdoc	30	4	11	45	$33,064	$25,671	$32,539
K08	Clinical Investigator Award to provide the opportunity for promising medical scientists to to pursue research and fill faculty gaps in shortage areas	Postdoc	151	3	268	422	$63,077	$68,818	$65,587
K11 K12	Physician Scientist Award. Support newly trained physicians nominated by institution for development of research skills and experience.	Postdoc	84		117	201	$64,450		$66,941
K14	Minority School Faculty Development Award. Encourage faculty investigators at minority schools	Postdoc	16	1	1	18	$56,623	$62,197	$48,233
K15 K16	Dentist Scientist Award. Similar to K11 for newly trained dentists	Postdoc	10	1	7	18	$64,128	$70,762	$61,382
Total			312	23	419	754	$57,816	$51,574	$64,113

NOTE: The number of trainees is calculated in terms of full-time equivalent positions (FTEP); one trainee for 12 months, rather than actual awards. Actual awards include individuals who were in the program for less than 12 months during 1987. K04 and K07 were excluded since these programs are not training. Cost data (from the Consolidated Grant Applicant File) contain only direct cost. They should not be interpreted as an indication of the total cost of the program.

SOURCE: Calculated by National Research Council from the NIH Consolidated Grant Applicant File.

and T35-like training programs. In FY 1988 NCI supported approximately 400 students in the laboratory research experience part of this program.[21]

- *Minority Biomedical Research Support (MBRS)*: This program was established in 1971 to provide salaries in order to enable minority students and faculty to acquire laboratory research experience by working on their own research projects while assisting on faculty projects. The program was funded at $39 million in 1988 and involved 100 minority institutions.[22] In 1988 the MBRS program supported 772 faculty, 1,095 undergraduate students, and 407 graduate students.[23]

- *Research Assistants (RAs) on NIH Research Grants*: A large volume of training occurs when graduate students gain experience and knowledge through their work as RAs to faculty on research grants. NIH research grants to faculty in graduate institutions therefore serve a twofold function: expanding the biomedical/behavioral knowledge base and providing research training. Given that research and development (R&D) grants have been growing at almost twice the rate of research training expenditures for the 1978-1987 period, the role of RAs in the NIH training enterprise may also have been growing in relative importance.[24] Graduate departments in the biological sciences indicated that 4,426 full-time graduate students were supported as RAs on NIH projects in 1987; this represented a 6.5 percent annual growth rate over the 2,673 NIH-supported RAs in 1979.[25] In psychology, NIH supported 334 RAs in 1979 and 382 in 1987.

GRANT APPLICATIONS AND AWARDS BY TRAINEES/FELLOWS

One indicator of the success of a training program is the ability of former trainees/fellows to obtain research grants.[26] Figure 1-3 presents 1987 percentages of postdoctoral trainees/fellows who have received NIH research grants (R01 activity code) since the scientists began NRSA research training in 1982. The committee was particularly struck by the fact that Ph.D. trainees received R01 grants at approximately three times the rate of M.D.s (10.3 percent versus 3.7 percent); for fellows, the comparable figures are 12.5 percent of M.D.s and 16.2 percent of Ph.D.s. Almost the same proportion of M.D. fellows (28.3 percent) applied for R01 grants, as did Ph.D. fellows (28.5 percent).

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[21]This information was provided from a personal communication with Vincent Cairoli of NCI, August 1989.

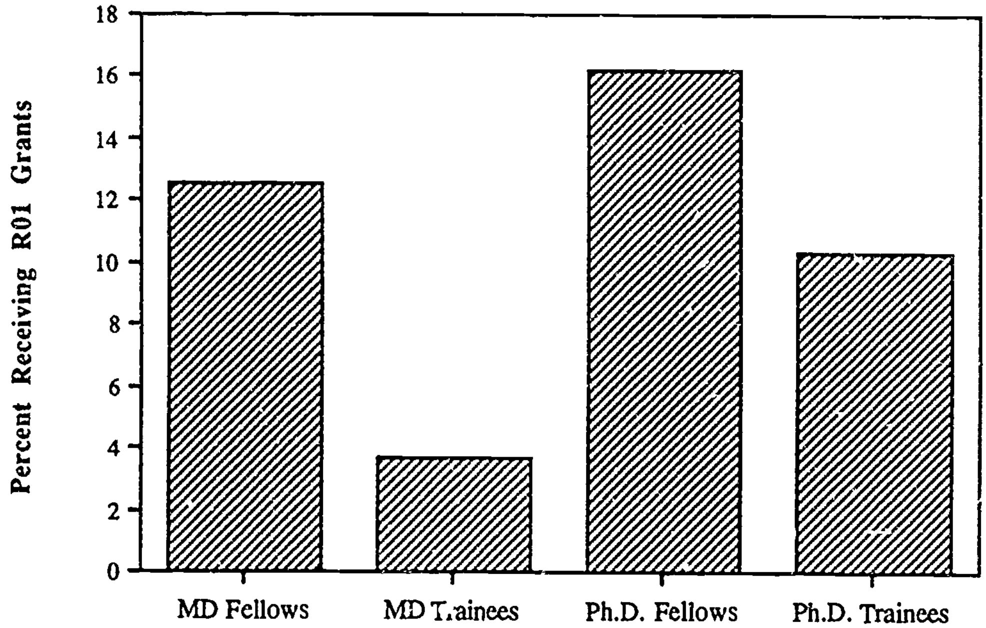
[22]See Michael Fluharty, "Recruiting Minority Students For the Biomedical Sciences," *The Chronicle of Higher Education*, July 12, 1989, p. B3.

[23]Data supplied by Ciraco Gonzales, Division of Research Resources, NIH, August 25, 1989.

[24]Total NIH R&D grants and contracts increased from $2.1 billion in 1978 to $4.9 billion in 1987 (10.0 percent annually); NIH research training expenditures increased from $148.5 to $238.8 million (5.4 percent annually) during the same period. See National Institutes of Health, *NIH Data Book 1988*, Table 16.

[25]These data are from the survey of graduate departments sponsored by the National Science Foundation and NIH, "Survey of Graduate Science and Engineering Students and Postdoctorates" (GSESP).

[26]See Chapter 4 for a discussion of NRSA program evaluation.



SOURCE: Appendix Table A-7.

Figure 1-3. Percent of NRSA postdoctoral trainees/fellows who received an R01 grant within five years after initiation of NRSA research training.

However, the difference is much larger for trainees: only 8.5 percent of M.D. trainees who began NRSA research training in 1982 applied for R01 grants, compared to 20.3 percent of the Ph.D. trainees.

HISTORICAL TRENDS

Table 1-5 contains FTEP data for the period 1978-1987 for NIH/ADAMHA NRSA training and fellowship programs. Estimates in Table 1-5 differ substantially from previous committee estimates of NRSA support levels.[27] There are several reasons for this difference:

1. The data in this report are based on the Trainee Fellow File (TFF) compiled from the records of individual trainees (Form 2271). Data in previous committee reports were based upon the Information for Management, Planning, Analysis and Coordination (IMPAC) file, which is compiled from grant applications by institutions that cover several traineeship positions, and are based upon proposed levels of support rather than actual level of support.

[27]See, for example, Institute of Medicine, *Personnel Needs and Training for Biomedical and Behavioral Research*, Washington, D.C.: National Academy Press, 1985, Tables 1.3 and 1.4.

Table 1-5. Historical Trends in NRSA Training Positions, 1978-1987

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Biomedical	6685	7181	8362	7781	7842	[illegible]	7820	7741	7808	7388
Predoctoral	3735	3974	4153	3767	4205	4021	3997	4008	3856	3681
Fellow	33	50	36	20	42	52	56	92	93	86
Trainee	3702	3924	4117	3746	4164	3969	3941	3916	3762	3594
Postdoctoral	2950	3207	4209	4014	3637	3649	3823	3733	3952	3707
Fellow	1676	1635	2214	1981	1505	1596	1727	1628	1817	1580
Trainee	1275	1572	1995	2033	2132	2053	2096	2106	2135	2127
Behavioral	692	733	619	484	1122	1012	966	971	962	924
Predoctoral	489	483	327	290	763	603	536	530	515	504
Fellow	107	95	58	30	49	31	20	40	33	37
Trainee	382	388	270	260	713	573	516	490	482	467
Postdoctoral	203	250	292	194	359	409	430	441	447	420
Fellow	163	166	188	93	95	114	92	91	91	95
Trainee	39	84	105	101	264	294	339	356	356	324
Clinical	2356	2406	1943	1939	2100	2143	2205	2195	2229	2157
Predoctoral	733	764	674	655	680	653	651	632	687	654
Fellow	3	1	1	1	3	3	6	2	6	17
Trainee	730	763	674	654	677	650	645	630	681	637
MSTP	462	547	646	652	676	646	645	629	661	636
Other	269	216	28	2	1	4	0	1	20	1
Postdoctoral	1623	1642	1269	1284	1420	1490	1554	1563	1542	1503
Fellow	318	330	197	226	195	151	184	181	139	113
Trainee	1305	1312	1072	1057	1225	1339	1370	1382	1403	1390
Total	9733	10320	10925	10204	11064	10824	10991	10908	10999	10468
Predoctoral	4958	5221	5155	4712	5648	5277	5184	5171	5058	4839
Fellow	143	147	95	52	94	85	81	135	132	141
Trainee	4815	5074	5060	4660	5554	5192	5103	5036	4925	4698
Postdoctoral	4775	5099	5770	5492	5416	5547	5807	5737	5941	5629
Fellow	2157	2131	2599	2300	1795	1861	2002	1899	2047	1788
Trainee	2619	2967	3171	3192	3621	3686	3805	3838	3894	3841
T35 Short-Term Training Total	NA	NA	573	836	902	1009	1029	900	730	774

NOTE: Totals may not add due to rounding. Table includes ADAMHA NRSA positions. Estimates are in terms of trainee/fellow years, i.e., one trainee/fellow for 12 months. Actual number of awards to individuals are higher due to partial-year awards. Field of trainee/fellows determined by degree/specialty/field data on individual trainee/fellow records (Form 2271). T35 program estimates are in number of awards and exclude T35 nontraining awards under the NHLBI T35 Minority Hypertension program. MSTP program is a subset of total predoctoral training for a joint Ph.D.-M.D. degree.

SOURCE: Estimated by National Research Council from the NIH Trainee Fellow File. For T35 program, data are from NIH Data Book 1988, Table 39; estimates of NHLBI T35 are estimated by National Research Council from the NIH Consolidated Grant Applicant File.

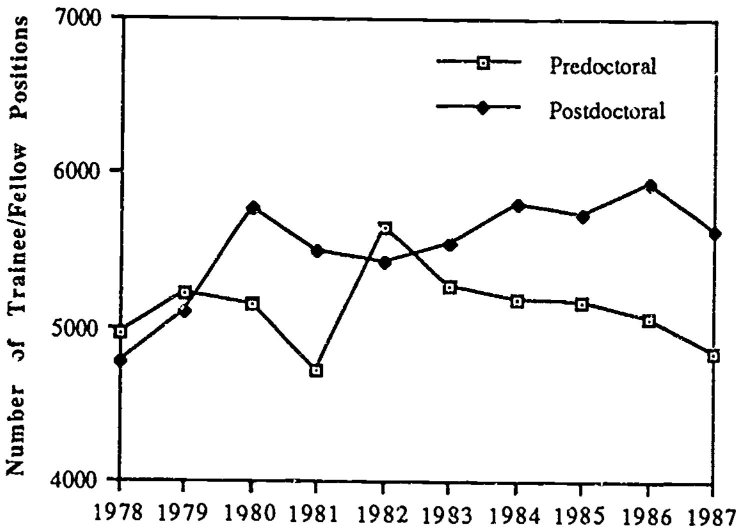
2. NIH constantly revises its files as information is updated. Estimates for earlier years (1984, for example) may change several times as these revisions occur. The data presented here are the most recent (August 1989) estimates available to the committee.

3. The estimates by field in this report are based on the degree/specialty/field code on the TFF. Earlier committee data were estimates of fields compiled from special tabulations developed by the NIH Division of Research Grants. In addition, the Consolidated Grant Applicant File (CGAF) records a single discipline code for all trainees, regardless of their actual field, whereas the TFF data reported here are based upon actual fields of the trainees.[28]

Figure 1-4 illustrates trends in predoctoral and postdoctoral FTEP support for the period 1978-1987. These are full-term (i.e., excluding T35) T and F program totals. Total years of support for postdoctoral positions have been increasing since the early 1980s, while predoctoral support has been declining. Total FTEP trainee/fellow support under the NRSA program peaked in 1982 at 11,063 positions and, after remaining near that level for four years, declined to 10,465 positions in 1987.

Figure 1-5 breaks out the number of FTEP positions supported in the biomedical sciences. Predoctoral positions have declined from a peak of approximately 4,200 in 1982 to approximately 3,700 FTEP in 1987. Postdoctoral positions have oscillated in the range 3,700-4,000 since 1984. Biomedical sciences have dominated the NRSA program historically, with 70.6 percent of all positions in 1987.

Figure 1-6 illustrates trends in trainee/fellow FTEP positions in the behavioral sciences. Predoctoral positions grew rapidly in 1982, but have since fallen off to about 500 positions. Postdoctorals in the behavioral sciences increased steadily from 194 FTEP in 1981 to a high of 447 positions in 1986. Behavioral science predoctoral support has remained around 10 percent of total NRSA predoctoral support for the 1978-1987 period; behavioral postdoctorals have increased proportionally during this period, from 4.3 percent in 1[illegible] to 7.5 percent in 1987.



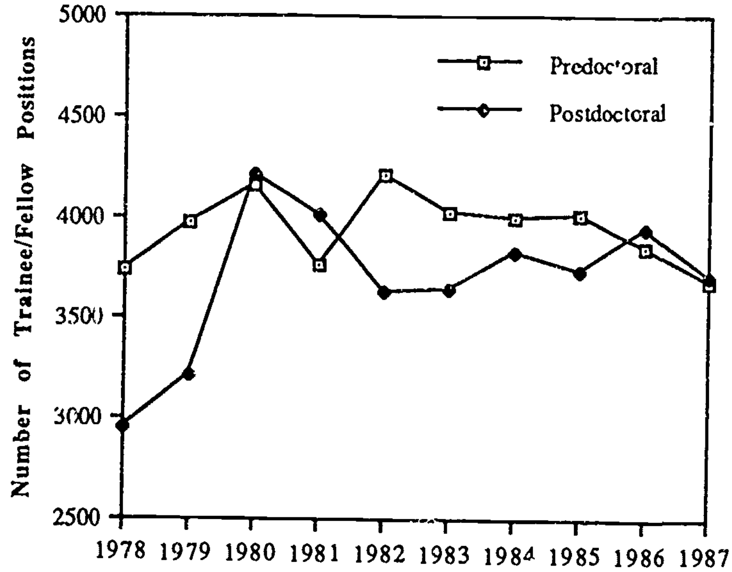
SOURCE: Table 1-5.

Figure 1-4. Total NIH/ADAMHA NRSA predoctoral and postdoctoral positions supported, 1978-1987.

[28]The disaggregation of trainees/fellows into fields is considered by some within NIH as an impossible task because of differences across institutes in program administration and definitions. The accuracy of these data is unknown. In the committee's opinion, improvement in the field classification of trainees/fellows is needed in the overall NRSA data base (see Chapter 5).

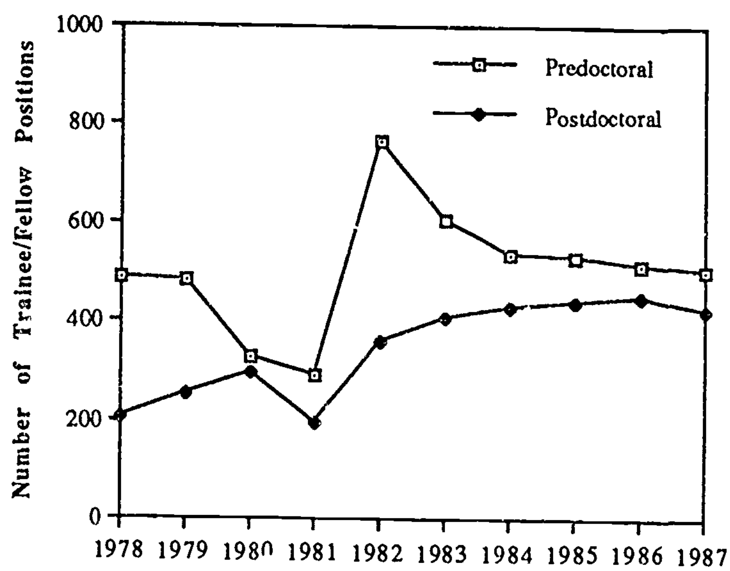
Figure 1-7 displays trend data on clinical sciences trainee/fellow FTEP positions for the period 1978-1987. Predoctoral support in the clinical sciences has remained flat, at approximately 650 positions since 1980; postdoctoral support increased initially, but flattened out at approximately 1,500 positions annually in 1983. Proportional support in the clinical sciences has been declining, from 14.8 percent to 13.5 percent of total NRSA predoctoral and from 34.0 percent to 26.6 percent of postdoctoral support during the 1978-1987 period.

The MSTP program has shown a fairly constant level of support during the 1980s at approximately 650 positions annually (Table 1-5). Short-term training (T35) grew to a peak of 1,029 in 1984, but the 1987 support in this program was 774 positions.



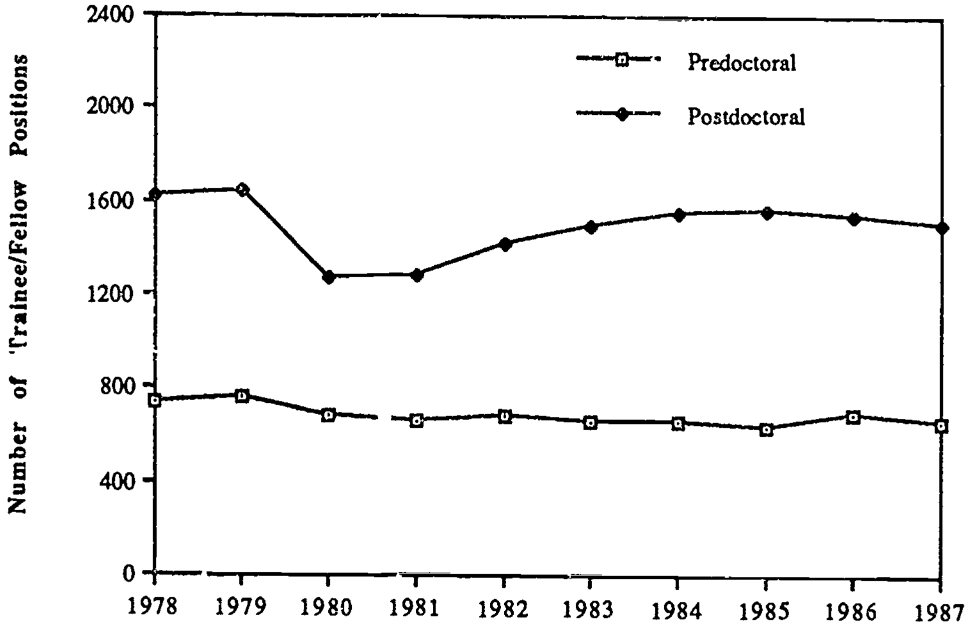
SOURCE: Table 1-5.

Figure 1-5. NIH/ADAMHA predoctoral and postdoctoral trainee/fellow positions in the biomedical sciences, 1978-1987.



SOURCE: Table 1-5.

Figure 1-6. NIH/ADAMHA NRSA predoctoral and postdoctoral trainee/fellow positions in the behavioral sciences, 1978-1987.



SOURCE: Table 1-5.

Figure 1-7. NIH/ADAMHA NRSA predoctoral and postdoctoral trainee/fellow positions in the clinical sciences, 1978-1987.

CHAPTER 2

THE CURRENT MARKET FOR BIOMEDICAL AND BEHAVIORAL SCIENTISTS

OVERVIEW

Labor markets for biomedical and behavioral scientists moved toward a balance between supply and demand in the 1980s after a period of excess supply in the 1970s. Biomedical scientists are in strong demand due to increased employment in industry; increased predoctoral enrollments have not yet produced an adequate supply of new biomedical Ph.D.s. The behavioral sciences have worked off the excess supply of the 1970s through continued employment growth and a decline in the number of new Ph.D.s. There are no reliable data on the supply and demand for physician/scientists.

Despite recent progress, minorities remain underrepresented among Ph.D. recipients and in the total work force of the biomedical and behavioral sciences. Female participation has increased more rapidly than minority participation, particularly by black males. However, many female Ph.D.s are not employed full-time in their scientific fields, with adverse consequences for personnel supply.

Foreign students received only 18 percent of biomedical Ph.D.s and 7 percent of behavioral Ph.D.s in 1988. However, most foreign students do not stay to work in the United States after graduation. Thus, foreign students contribute relatively little to the growth of biomedical and behavioral sciences work force.

THE CHANGING LABOR MARKET FOR BIOMEDICAL AND BEHAVIORAL SCIENTISTS, 1973-1987

The size and composition of the scientist work force are determined by three flows: *new entrants*, usually new degree recipients; *attrition*, in the form of deaths and retirements; and net gains or losses due to occupational *mobility*. New entrants serve the dual purpose of offsetting attrition and permitting growth. The adequacy of supply of new entrants depends on whether their numbers exceed, equal, or fall short of the replenishment needs and growth needs of the work force. As a result, the accurate measurement of these three processes is basic to any study such as this.

Refreshment Rates

Figure 2-1 shows the attrition and refreshment rates for biomedical scientists--that is, the number of new Ph.D.s as a percent of those employed in that field.[1] Attrition rates are the percentage losses due to death, retirement, and net mobility.[2] Refreshment minus attrition is the percentage available for growth in employment in the field. In 1974, for

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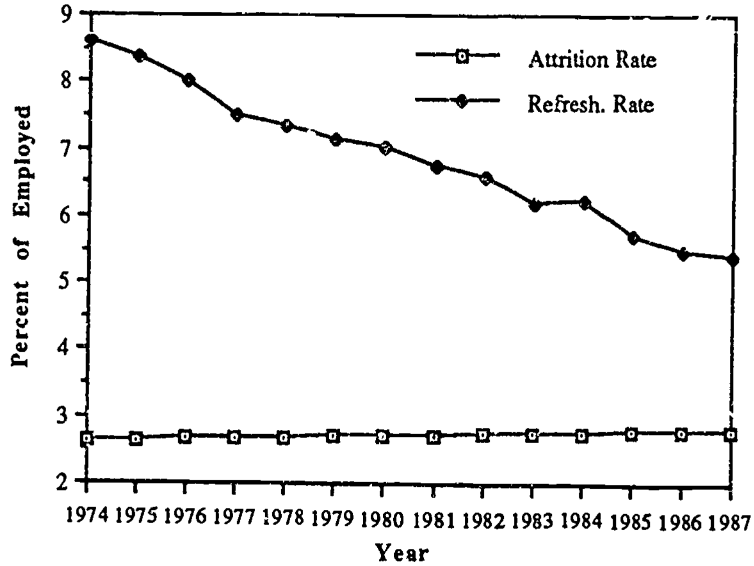
[1]Obviously, not all new Ph.D.s in biomedical science go into the field; also, the field draws Ph.D.s from other areas (e.g., physical sciences, other life sciences) and from foreign scientists. However, the primary supply source of new Ph.D.s is U.S. graduates in the field, and thus the refreshment rate gives one a sense of the historical relationship between this supply source and demand.

[2]Net mobility is the difference between scientists leaving the biomedical field for other pursuits and scientists entering biomedical science from other employment.

example, new Ph.D.s comprised 8.6 percent of total employment in the biomedical sciences, while losses from attrition were 2.6 percent of employment; this left a net of 6.0 percent available for growth in employment of people trained in the field. By 1987, however, refreshment was 5.4 percent, attrition 2.8 percent, and the potential for growth only 2.6 percent. Actual employment growth, 4.1 percent that year, was achieved by drawing new entrants from other fields.

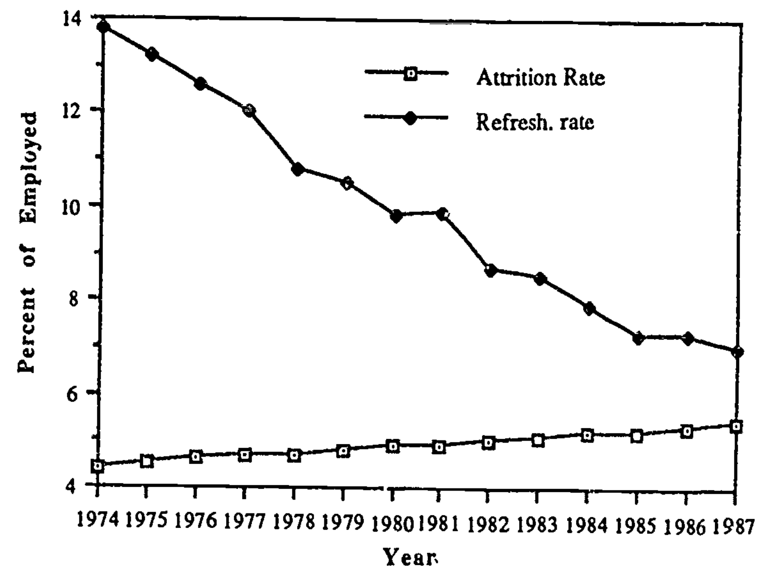


SOURCE: Appendix Table A-8.

Figure 2-1. Refreshment and attrition in biomedical science, 1973-1987.

During the 1980s, the biomedical field averaged 4,500 job openings annually (1,080 scientists lost from deaths and retirements, 620 scientists lost from net mobility, and growth requirements of 2,800). Average annual biomedical Ph.D. production during the period was only 3,840. This contrasts sharply with the 1970s, when average annual job openings from all sources were 3,660 and average annual Ph.D. production was 3,520. Clearly, the supply of new biomedical Ph.D.s has begun to fall short of the number of job openings in the late 1980s after an extended period of approximate balance. In the behavioral sciences, on the other hand, new Ph.D.s have exceeded new job openings throughout the 1970s and 1980s.

Figure 2-2 shows that the refreshment rate for behavioral scientists (excluding clinical psychologists) has also been decreasing. In 1973 attrition amounted to 4.4 percent of those employed and refreshment was 13.8 percent, leaving 9.4 percent for growth; actual growth was 8.6 percent. In 1987, attrition was 5.4 percent, and refreshment was 7.0 percent, leaving 1.6 percent for growth; and indeed actual growth was only 1.2 percent.



SOURCE: Appendix Tables A-9 and A-10.

Figure 2-2. Refreshment and attrition in nonclinical psychology and other behavioral sciences, 1973-1987.

Attrition

Figure 2-3 presents estimates of the rate of exit from the science work force due to death and retirement. These

rates increase sharply for scientists over 55 years of age.[3]

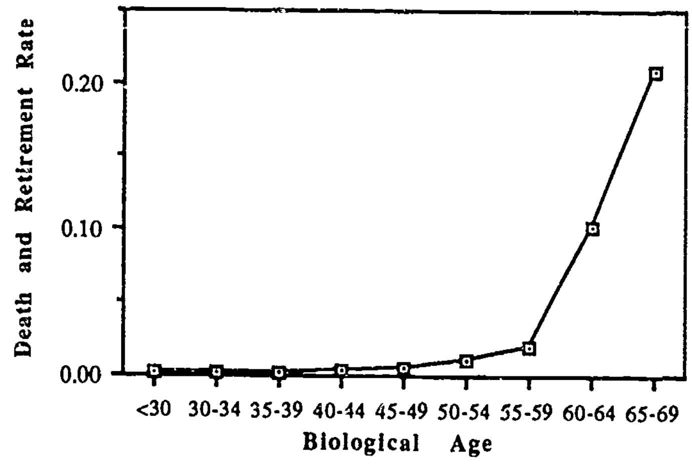
Net Mobility

Scientists who leave biomedical science for other employment must usually be replaced.[4] Figure 2-4 shows estimates of these net rates of mobility (outmobility less inmobility from other fields) based upon historical data.[5] These exit rates are a function of scientists' "career age" (years since Ph.D. degree); Figure 2-4 shows that the rate increases as a scientist matures.

Obviously, scientists from a wide variety of degree fields (e.g., physical science, behavioral science) work as biomedical scientists. The net mobility rates used here are based on field of employment, regardless of the scientist's degree field. Once scientists gain employment either in a biomedical field or in a nonbiomedical field, they are identified by that employment field rather than their field of degree.

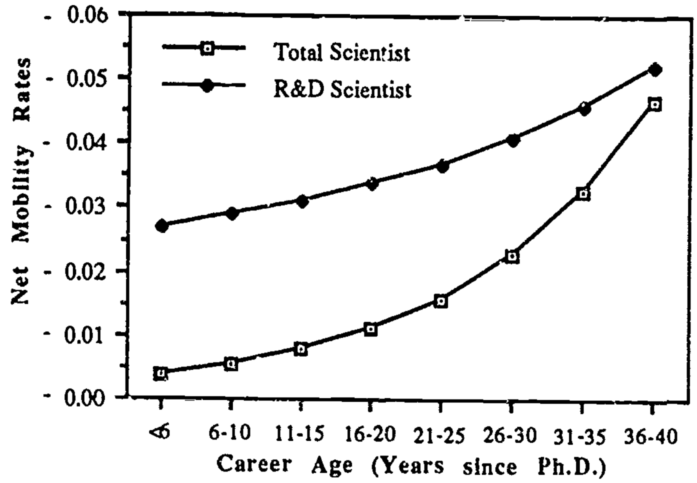
RECENT TRENDS IN THE LABOR MARKET FOR BIOMEDICAL SCIENTISTS

Figure 2-5 displays patterns of employment for biomedical scientists in 1987 by employment sector and by primary work activity--R&D or



SOURCE: Appendix Table A-16.

Figure 2-3. Death and retirement rates for scientific employment.



SOURCE: Calculated from Appendix Table A-17.

Figure 2-4. Net mobility rates for total and R&D biomedical scientists by career age.

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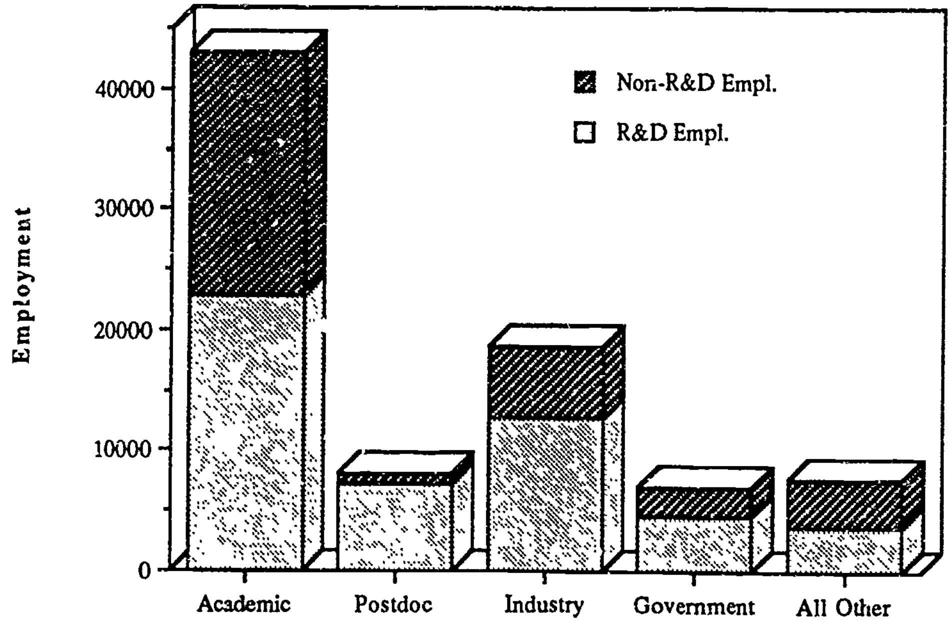
[3]For a more detailed discussion of the model used to estimate scientist attrition, see Joe G. Baker, "Biomedical/Behavioral Cohort Model: A Technical Paper," contained in volume III of this report.

[4]Biomedical scientists are lost from the work force when they move into university administration, industrial management, or other non-science occupations. This loss is partially offset by individuals who move into biomedical science from non-science. The net mobility estimates used here are the difference between these two labor flows.

[5]The rates in Figure 2-4 are for biomedical scientists only; separate rates were computed for behavioral scientists.



SOURCE: Appendix Table A-2.

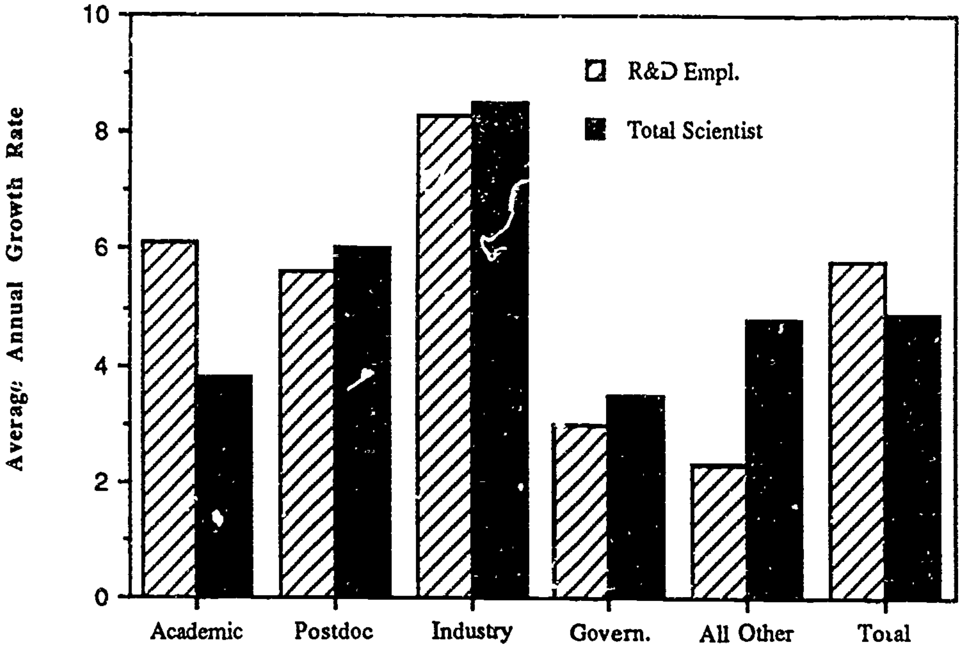
Figure 2-5. 1987 biomedical science Ph.D. employment, by R&D activity and employment sector.

the management of R&D, and non-R&D.[6] An estimated 76,300 Ph.D. scientists identified their work as biomedical science, and another 8,200 were undertaking postdoctoral study in the biomedical sciences. Academic employment (43,000 scientists) and industrial employment (16,000 scientists) were the largest sectors. Overall, 60.5 percent of all biomedical scientists indicated that their primary work activity was R&D or the management of R&D.

Growth in Employment

Figure 2-6 shows the growth in employment of biomedical scientists between 1973 and 1987. Total employment plus postdoctorates nearly doubled, from 43,000 in 1973 to 84,500 in 1987, an annual rate of growth of 4.9 percent. Industrial employment increased at over twice the rate of academic employment. The proportion of biomedical scientists who indicated that their primary work activity was R&D or the management of R&D also

[6]In the Survey of Doctorate Recipients (SDR), respondents are asked to identify their primary work activity. In this report, those respondents who identified their primary work activity as R&D or the management of R&D are classified as R&D scientists; all other scientists are classified as non-R&D scientists. Obviously, some (or most) of these non-R&D scientists devote some portion of their work activity to R&D; however, it is not treated as their primary activity. The R&D/non-R&D dichotomy is used to indicate differences in research intensity among employment sectors and through time.



SOURCE: Appendix Table A-2.

Figure 2-6. Average annual growth rates for R&D and total biomedical Ph.D. employment, 1973-1987.

increased during this period, from 53.6 percent in 1973 to 60.5 percent in 1987.[7] This was the result of two basic trends:

1. a growth in the proportion of total employment made up of private industry, in which more than three-fourths of biomedical scientists are engaged in R&D; and

2. an increase in the percentage of academic scientists who indicate that their primary work activity is R&D.

The annual average increase in the number of biomedical scientists engaged in R&D has been 5.8 percent for the 1973-1987 period, slightly higher than overall growth in the field.

Postdoctoral Appointments

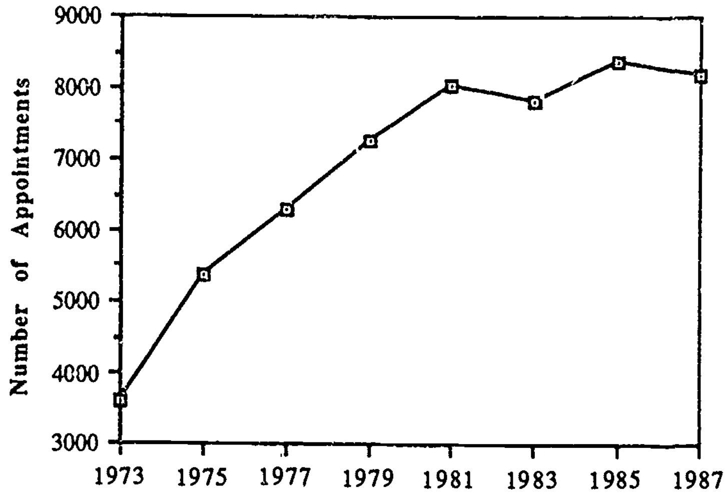
Figure 2-7 shows that the number of postdoctoral training positions in the biomedical sciences grew rapidly through the 1970s, but has since plateaued near the 1981

[7]These estimates are from the NAS/NRC, Survey of Doctorate Recipients (SDR).

level.[8] These trends are consistent with the evidence that new job openings exceeded new Ph.D.s in the late 1980s.

Trends in Job Openings and Ph.D. Production

Using the death and retirement rates from Figure 2-3, one can estimate attrition from the work force of biomedical scientists based on age distribution. For the period 1973-1977, deaths and retirements from the stock of biomedical scientists averaged approximately 730 per year. In the later period 1983-1987, the number of annual deaths and retirements averaged 1,200, a 64-percent increase over the earlier period.



SOURCE: Appendix Table A-2.

Figure 2-7. Postdoctoral appointments of biomedical scientists, 1973-1987.

For the period 1973-1977, there was a net loss of approximately 450 biomedical scientists per year to other employment. These losses were replaced by new hires. Because of employment growth and changes in the career age distribution, this net migration grew to approximately 670 per year in the period 1983-1987. By the late 1980s, therefore, the need to replace attrition with new Ph.D.s had grown substantially. The aggregate annual attrition of approximately 1,200 consumed one-third of the yearly biomedical Ph.D. production of 3,500 Ph.D.s during the 1973-1979 period. For the period 1979-1987, annual attrition grew to 1,700 and consumed almost half of the annual biomedical Ph.D. output of 3,850.[9] Indeed, at current rates of employment growth and Ph.D. output, attrition replacement will equal new biomedical Ph.D. output by the end of the century.

Figure 2-8 compares the number of job openings by source with the annual production of new biomedical Ph.D.s for the period 1973-1987. It shows a growing gap between supply of and demand for new Ph.D.s. Biomedical science Ph.D. awards totaled 3,520 in 1973; this grew to 3,960 in 1982 and has been relatively flat since then. As a result, there was approximately one job opening per new Ph.D. for the period 1973-1979, but for the period 1979-1987 there were on average 1.17 job openings for each new Ph.D.

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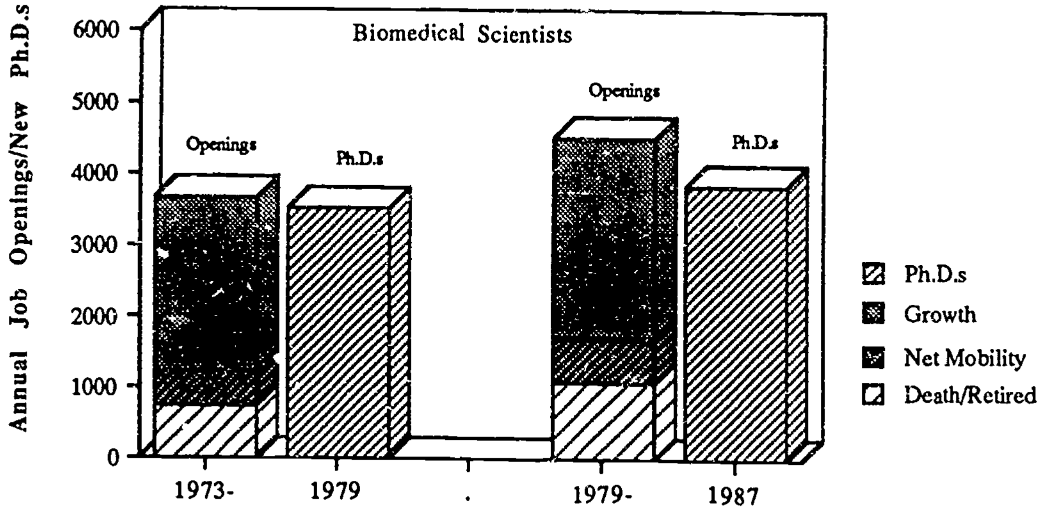
[8]There are two sources of data for postdoctoral appointments in the biomedical sciences: the SDR and the National Institutes of Health/National Science Foundation's Survey of Graduate Science and Engineering Students and Postdoctorates (GSESP). The SDR data are used here.

[9]Because death and retirement are a function of biological age and net mobility is a function of career age, the overall attrition rate of the work force is related to its career and biological age structure. In the 1980s, death and retirement were approximately 1.9 percent per year and net mobility approximately 1 percent per year. See Joe G. Baker, *op cit.*



SOURCE: Appendix Table A-8.

Figure 2-8. Average annual job openings and new Ph.D.s in the biomedical sciences, 1973-1979 and 1979-1987.

People and institutions seem to have responded to this imbalance between job openings and new Ph.D.s in the biomedical sciences.[10] Real wages increased for biomedical scientists in the late 1980s, as they did for all Ph.D.s. In response, graduate enrollments in the biomedical sciences (both doctoral and master's levels), which had declined to a low of 41,191 in 1983, have since grown steadily to 44,495 in 1987. First-year graduate enrollments in doctorate-granting institutions have risen from only 8,043 in 1983 to 8,609 in 1987. However, the enrollment response requires several years before numbers of new Ph.D.s are affected.[11]

RECENT TRENDS IN THE LABOR MARKET FOR BEHAVIORAL SCIENCES

Behavioral scientists are composed of three basic groups according to the NRC nomenclature: *clinical psychologists, nonclinical psychologists*, and *other behavioral scientists* (anthropologists, sociologists, audiologists, and speech pathologists).

Clinical Psychology

Psychologists, who form the majority of behavioral scientists, have available an alternative to the standard research career pattern. This consists of independent practice in the broad areas of clinical and counseling psychology. Concerned with patient care

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[10]See Joe G. Baker, "The Ph.D. Supply Crisis: A Look at the Biomedical Sciences," paper given at the Western Economics Association Meeting, June 21, 1989, Lake Tahoe, Nevada.

[11]The supply consequences of increasing enrollment were partially offset by increasing time to complete doctoral studies. For a more complete discussion of increasing time to the doctorate, see H. Tuckman, et al., *On Time to the Doctorate*, (Washington, D.C.: National Academy Press, forthcoming. See also Joe G. Baker, "The Ph.D. Supply Crisis."

rather than research, this career path resembles that of the practicing M.D. Doctorates in psychology are usually obtained from university departments, although professional schools of psychology are being accredited to provide doctorates in clinical and counseling fields that are oriented toward service and/or administration.

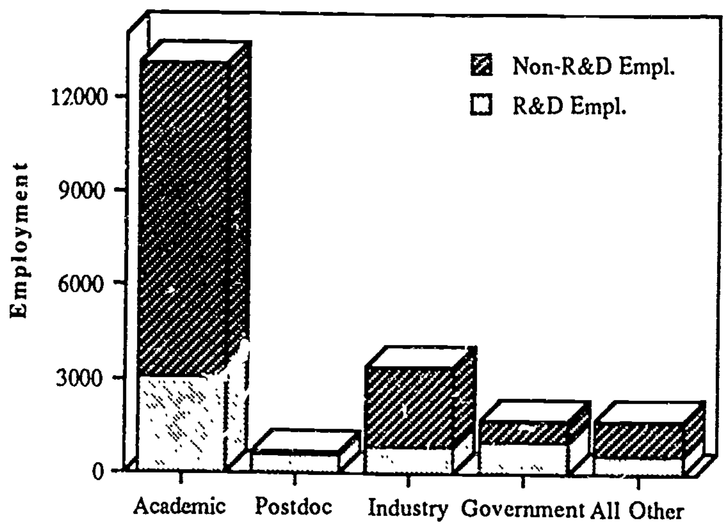
Only about 1,200 out of a population of 33,388 clinical psychologists (less than 4 percent) are engaged primarily in R&D or the management of R&D. Given the applied nature of clinical psychology, this report focuses on nonclinical psychologists and other behavioral scientists.[12] Nonclinical psychologists usually will be referred to simply as psychologists hereafter.

Nonclinical Psychology

The market for psychologists is dominated by the academic sector, which employed 63.7 percent of the 1987 total of 20,510 psychologists (Figure 2-9). Industry employed another 16.5 percent, and the remaining 20 percent of employment was scattered across other sectors. In 1987, 29.9 percent of all psychologists indicated that their primary work activity was R&D or the management of R&D.

Industrial employment grew at over twice the rate of the academic sector between 1973 and 1987 (Figure 2-10). Nonclinical psychology degree holders have also been attracted to employment in clinical psychology.[13] Employment of psychologists increased at an annual rate of 3.2 percent from 1973-1987. Postdoctoral appointments in psychology are few compared to biomedical fields, increasing from 259 in 1973 to 666 in 1987.

For the period 1973-1979, an average of 230 psychologists retired or died annually and approximately 430 were lost each year to net mobility. The sum of these two losses--660--represented about 41 percent of annual new nonclinical psychology Ph.D.s (1,591). For



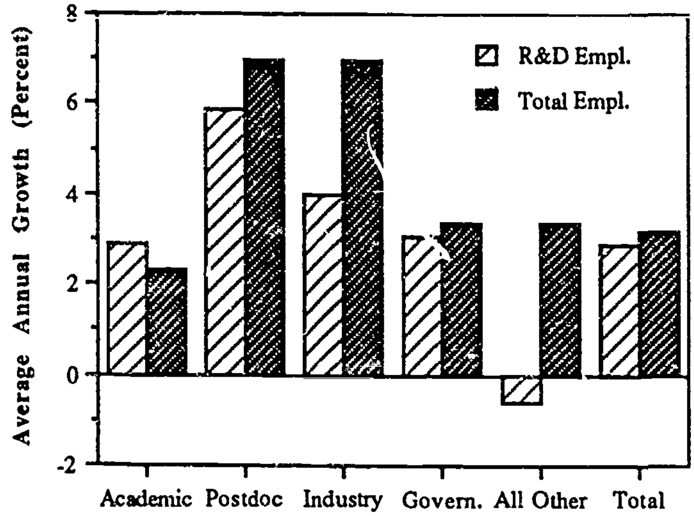
SOURCE: Appendix Table A-3.

Figure 2-9. 1987 Ph.D. Employment of nonclinical psychologists by R&D activity and employment sector.

[12]In 1987, an estimated 421 Ph.D.s were doing postdoctoral work in clinical psychology. The employment growth of clinical psychologists was substantial for the 1973-1987 period, averaging 7.9 percent annually; but most of this growth was concentrated in the practice sector (where fewer than 0.1 percent of clinical psychologists are active in R&D). These data are from the Survey of Doctorate Recipients.

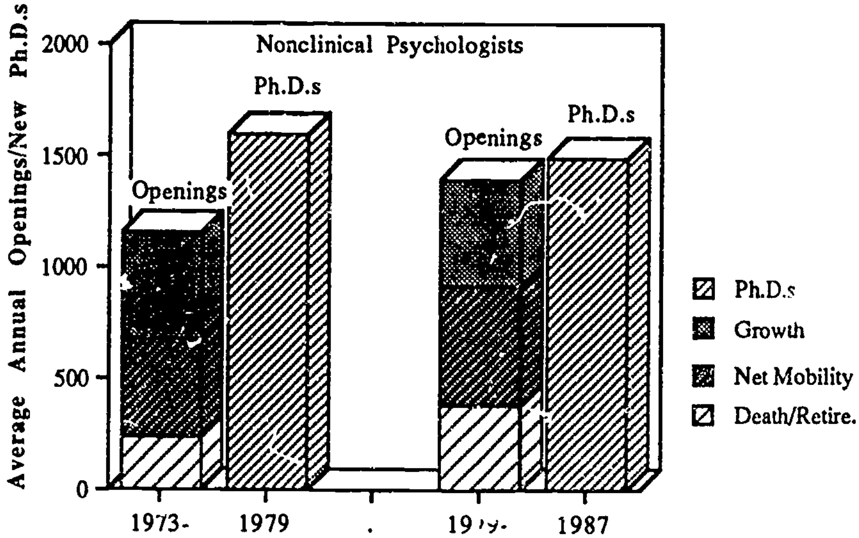
[13]In 1987, 16.1 percent of all employed clinical psychologists had earned their Ph.D.s in nonclinical psychology, and another 5 percent came from other fields. The reverse movement, from clinical to non-clinical psychology, was almost identical--16 percent, according to the Survey of Doctorate Recipients.

the period 1983-1987, attrition from death and retirement grew to 380 annually, and mobility to 540; this aggregate annual attrition of 920 represented 62 percent of average new Ph.D. production of 1,485.[14] As shown in Figure 2-11, there were about 0.7 job openings for each new nonclinical psychology Ph.D. in the period 1973-1979, rising to approximately 0.9 job openings per each new Ph.D. in the period 1979-1987. The labor market of the 1980s for nonclinical psychologists thus seems more in balance, both as a result of increasing openings (primarily from attrition) and a decline in the average number of nonclinical psychology Ph.D.s produced, from 1,591 per year (1973-1979) to 1,485 per year (1979-1987).



SOURCE: Appendix Table A-3.

Figure 2-10. Average annual Ph.D. employment growth for R&D and total nonclinical psychologists, 1973-1987.



SOURCE: Appendix Table A-9.

Figure 2-11. Average annual job openings and new Ph.D.s in nonclinical psychology, 1973-1979 and 1979-1987.

Other Behavioral Sciences

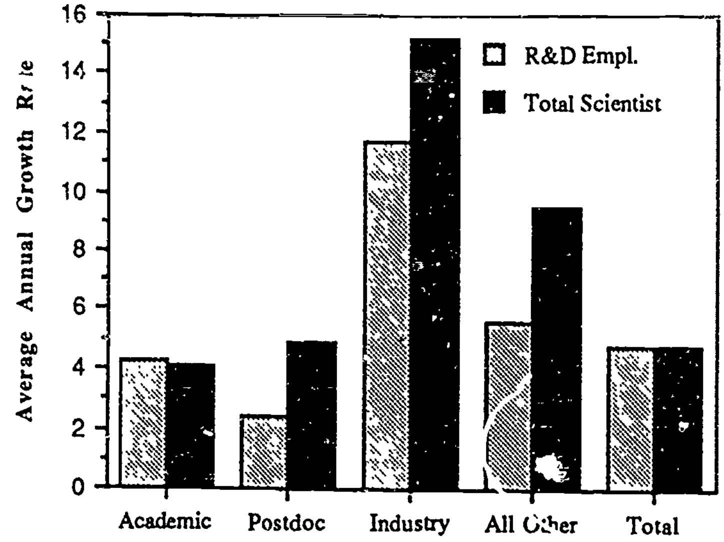
Employment in these fields increased at an annual rate of 4.8 percent for the 1973-1987 period (Figure 2-12). However, the growth rate for the 1983-1987 period slowed to 0.3 percent annually, and academic employment actually declined during the period. Academic employment of other behavioral scientists dominates their labor market: in 1987 almost 85 percent of academic employment was in colleges and universities, with the remaining 15 percent scattered across other employment categories. In 1987, total employment in other behavioral sciences was 12,735 (excluding 192 postdoctorates).

Other behavioral scientists engaged primarily in R&D averaged about 9 percent

[14]For a more detailed discussion of the model used to estimate scientist attrition, see Joe G. Baker, "Biomedical/Behavioral Cohort Model: A Technical Paper," in Volume III of this report.

of total employment for the entire 1973-1987 period. Approximately 15 percent of those academically employed indicated that their primary work activity was in R&D. Postdoctoral appointments of other behavioral scientists comprised only 1.4 percent of the total work force in 1987.

In recent years, the majority of job openings for other behavioral scientists have resulted from attrition. Death and retirement (130 average annual openings) and negative net mobility (250 average annual openings) resulted in approximately 380 job openings annually during the 1973-1978 period; new growth required almost 780 scientists annually. In the 1983-1987 period, death and retirement (280 openings) and net mobility (370 openings) both exceeded annual growth positions (approximately 220 new Ph.D.s).



SOURCE: Appendix Table A-4.

Figure 2-12. Average annual growth in Ph.D. employment of other behavioral scientists by total and R&D, 1973-1987.

Degree production in other behavioral sciences fell steadily, from 1,307 Ph.D.s in 1976 to 882 in 1987, mirroring the decline in annual openings. The number of job openings per new other behavioral sciences Ph.D. had not changed substantially during the 1973-1987 period, ranging from 0.85 to 0.95 openings per each new Ph.D. Scientists who hold Ph.D.s in other behavioral science fields have also sought employment in other fields as a result of this soft market: in 1987 only about half of all scientists with Ph.D.s in other behavioral science fields were working as other behavioral scientists, compared with 71.9 percent in 1972.

RECENT TRENDS IN THE LABOR MARKET FOR PHYSICIAN/SCIENTISTS

There is no precise tally of physician/scientists currently active in biomedical research, but indirect indicators point to a predominance of activities other than research. An example is a 1983 survey of full-time faculty within the departments of medicine at U.S. medical schools approved by the Liaison Committee on Medical Education (LCME).[15] Faculty in departments of medicine are traditionally viewed as being more involved in research activities than faculty from other clinical departments. The data from this survey can be used as an approximation of the upper limits of research effort for all full-time faculty. The survey found that 50 percent of the full-time faculty physicians spent less than 25 percent of their time conducting research; only 20 percent spent more than half of their time in research endeavors. This suggests that the expanding pool of full-time clinical faculty in medical schools (Figure 2-13) is a response to increasing patient care activities by clinical departments and does not reflect an increasing supply of

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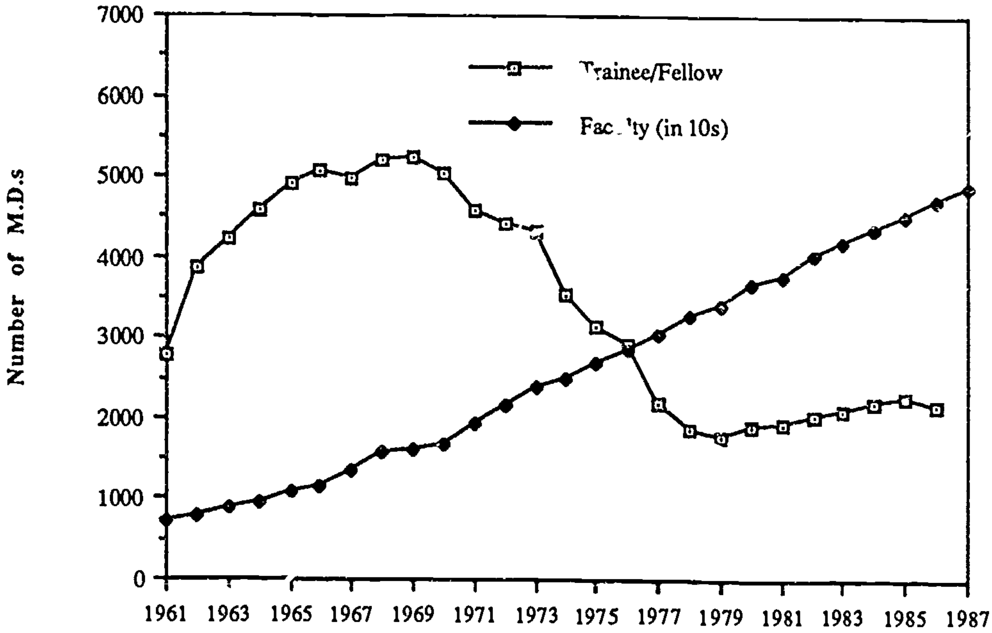
[15]H. N. Beaty, et al., "Research Activities of Faculty in Academic Departments of Medicine," *Annals of Internal Medicine*, vol. 104, 1986, pp. 90-97.



SOURCE: Appendix Table A-11.

Figure 2-13. Trends in M.D. postprofessional training and medical school faculty, 1961-1987; faculty in tens (e.g., 1976 = 28,603 faculty members and 2,918 trainees/fellows).

physician/scientists. Extrapolating from this survey, it can be estimated that, at most, only 20-30 percent of the full-time faculty in all clinical departments are actively engaged in biomedical research.

Several earlier studies also document the declining numbers of physicians entering careers in scientific investigation.[16] As a case in point, the number of physicians in research training programs sponsored by NIH decreased, from approximately 4,200 in 1969 to 1,910 in 1977 and has not increased significantly since then (see Figure 2-13).[17] This decline is explained, in part, by changes in program policy--much of the support in the 1960s and early 1970s was for training in medical subspecialities and required no research

[16]See, for example, S. O. Thier, et al., "Proposals Addressing the Decline in the Training of Physician Investigators: Report of the Ad Hoc Committee of the AAMC," *Clinical Research*, 1980, pp. 85-93; J. B. Wyngaarden, "The Clinical Investigator as an Endangered Species," *New England Journal of Medicine*, vol. 301, 1979, pp. 1,254-1,259; and G. F. DiBona, "Whence Cometh Tomorrow's Clinical Investigators?", *Clinical Research*, vol. 27, 1979, pp. 253-256.

[17]G. M. Carter, A. Robyn, and A. M. Singer, "The Supply of Physician Researchers and Support for Research Training: Part I of an Evaluation of the Hartford Fellowship Program," report N-2003-HF, (Santa Monica, CA: The Rand Corporation, 1983), pp. 46-47.

focus. Regardless, the number of physician trainees has not kept pace with growth in the physician population.

Data for NIH grant awards provide another indicator of declining research activity by full-time faculty with the M.D. degree versus those with a Ph.D. degree.[18] Of 11,683 grants in 1970, 36.7 percent (4,289) were awarded to M.D. principal investigators, 51.3 percent (5,993) to Ph.D.s, 5.9 percent (693) to M.D./Ph.D.s, and 6.1 percent (708) unknown. By 1987, when 24,384 grants were awarded, 26.2 percent (6,393) went to M.D.s, 63.9 percent (15,589) to Ph.D.s, 3.7 percent (902) to M.D./Ph.D.s, and 6.1 percent (1,498) unknown. Although the number of grants to M.D.s increased, their share of total growth fell.

COMPOSITION OF THE LABOR FORCE

Race and Sex

Over the past decade, those concerned with the scientific work force have researched and written extensively about the underrepresentation of women and minorities in that sector.[19] This concern is motivated by reasons of both equity and strategy. But while the composition of the scientific work force reflects increasing numbers of individuals other than the traditional pool of white males, the participation of women and minorities in science is still far lower than their participation in the overall labor force. For instance, nearly 45 percent of the 1987 U.S. labor force was made up of women, but only about 22 and 34 percent of biomedical and behavioral scientists were female.[20]

The distribution of minorities in science differs even more sharply from that in the larger labor force: blacks and all other minorities except Asians are underrepresented by factors of 6 or 7. In addition, while the percentage of women in the scientific work force is growing at a relatively rapid pace, the growth in the number of racial and ethnic minority scientists is painfully slow.

An important trend in the general labor force also holds for biomedical/behavioral doctorate recipients: a much more rapid growth in the rate of entry for women than for men. Although the number of awards to minority males in biomedical science grew only slightly between the time period 1978-1982 and the time period 1983-1987 (3.61 percent), growth in the number of awards to minority women (27.5 percent) resembled that of white women. The trends were similar in the behavioral sciences, where female participation is

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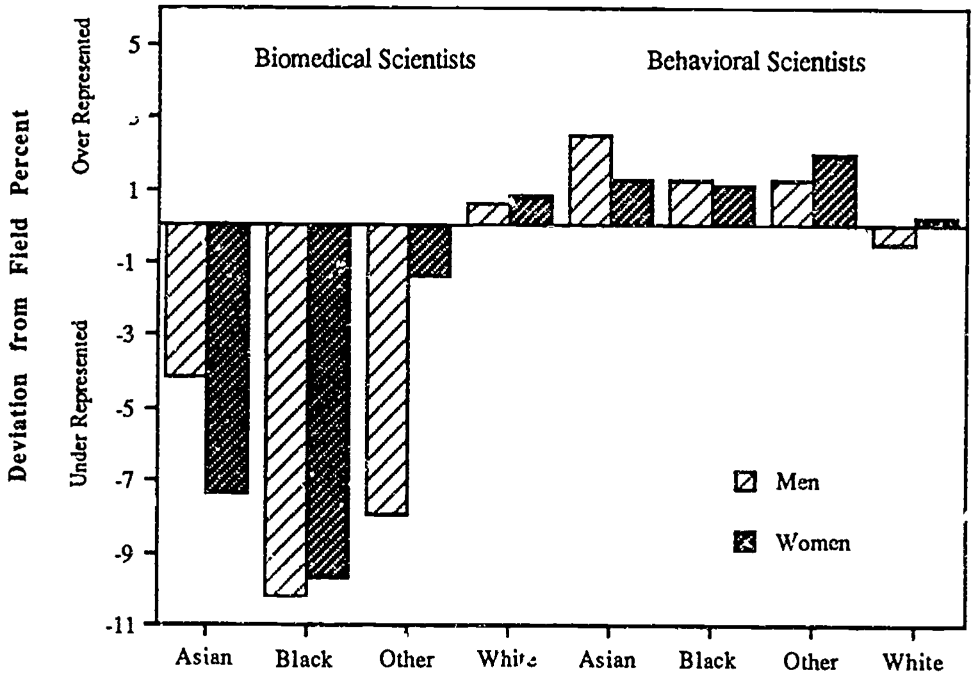
[18]B. Healy, "Innovators for the 21st Century: Will We Face a Crisis in Biomedical-Research Brainpower?," *New England Journal of Medicine*, vol. 319, 1988, pp. 1,059-1,064.

[19]See, for instance, The White House Task Force on Women, Minorities and the Handicapped in Science and Technology, *Changing America: The New Face of Science and Engineering*, Washington, D.C.: September 1988; National Science Foundation, *Women and Minorities in Science and Engineering*, Washington, D.C.: U.S. Government Printing Office (a biennial publication beginning in 1982); National Research Council, *Women: Their Underrepresentation and Career Differentials in Science and Engineering*, Washington, D.C.: National Academy Press, 1987; National Research Council, *Minorities: Their Underrepresentation and Career Differentials in Science and Engineering*, Washington, D.C.: National Academy Press, 1987; and Government-University-Industry Research Roundtable, *Nurturing Science and Engineering Talent*, Washington, D.C.: National Academy Press, 1987.

[20]Data are from National Research Council, Survey of Doctorate Recipients, 1987; and Council of Economic Advisors, *Economic Report of the President 1989*, Washington, D.C.: U.S. Government Printing Office, 1989.

traditionally higher; by the mid-1980s, over half of all behavioral Ph.D.s were being awarded to women. Comparable data are not available for physician/scientists.

To determine whether there is an association between race or sex and the careers of biomedical and behavioral Ph.D.s, the committee examined predoctoral support, postdoctoral plans, and a career outcome of those in the doctoral labor force in the biomedical and behavioral sciences.[21] Figure 2-14 indicates that the distribution of NIH predoctoral support to graduate students is not independent of race and sex in some cases. Both this figure and the two that follow show percentage point deviations of the race/sex groups from their respective field percentages. For instance, 23.3 percent of all biomedical degree recipients in the period 1983-1987 reported NIH as the primary source of support in graduate school. The comparable figure for black women in that group was 13.6 percent or 9.7 percentage points below the field percentage; in other words, black women were 9.7



SOURCE: Appendix Table A-12.

Figure 2-14. Under- and over-representation of race/sex groups in NIH predoctoral support for biomedical (field percent = 23.3) and behavioral (field percent = 2.9) doctoral recipients, 1983-1987.

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[21]The first group contains so few minority members in any given year that the committee, using the National Research Council's Survey of Earned Doctorates (SED), aggregated cohorts of doctorate recipients over two five-year periods to investigate both differentiation and change. For the same reason, it would have been desirable to aggregate across cohorts of the Survey of Doctorate Recipients (SDR), used for compilation of the second group, but the longitudinal nature of the SDR would have involved multiple counting of individuals. Hence, the two single years, 1977 and 1987, were selected for analysis of these populations.

percent underrepresented. The reasons for this are not known, however, and the numbers are small. Figure 2-14 shows that minority groups are uniformly underrepresented among basic biomedical doctorate recipients reporting NIH as their primary source of predoctoral support. In the behavioral fields, the situation is reversed, but the deviations are trivial.

The underrepresentation of minority graduate students with NIH support is surprising, given major efforts to target minorities within NIH/ADAMHA. In addition to the MARC program, noted in the Executive Summary, NIH provides summer research apprenticeships for minority high school students, research grant supplements for projects that employ minority students or faculty, and strong directives to grant applicants and internal staff concerning procedures for recruiting minorities.[22] Despite these efforts, the growth of the minority doctoral population in these fields has been slow. Possible explanations for the inconsistency between the size of the NIH/ADAMHA minority programs and low levels of actual minority student support include the following:

- The major mechanism for predoctoral support within NIH/ADAMHA is the T32 institutional training program. The selection of individual applicants in these programs is left up to the institutions. NIH/ADAMHA requires schools receiving T32 grants to have a minority recruitment program; it is not known how effective the individual institutions are in recruiting minorities nor how underrepresented minorities may be in the institutions.

- The NIH/ADAMHA minority programs may simply be ineffective. For example, if minorities have higher attrition rates and longer time to degree than other students, fewer Ph.D.s are produced per given level of predoctoral support. Thus NIH/ADAMHA support for predoctoral minority students may be high, but relatively few of these students may receive Ph.D.s.

- The inconsistency between NIH/ADAMHA minority programs and actual levels of minority student support may be due to data bias. Students responding to the Survey of Earned Doctorates may not be sure what their source of support was during graduate school.[23]

The causes of the low levels of minority student support and Ph.D. awards are clearly a cause for concern. The committee recommends program evaluations and pipeline studies as a start to sort out the causes of these troubling statistics (see recommendations in chapter 5).

To learn about postdoctoral plans, the committee relied on the SED, which asks whether respondents have definite plans for future study or employment at the time of completing the survey form, usually when the dissertation is accepted; those who answer negatively are displaying ambiguity about their careers. Figure 2-15 displays the levels of such uncertainty and any possible differentials by field, race, and sex; every measured effect operates in ways that are highly significant, both statistically and substantively. For example, about 9 percent fewer behavioral than biomedical majors report definite plans. A

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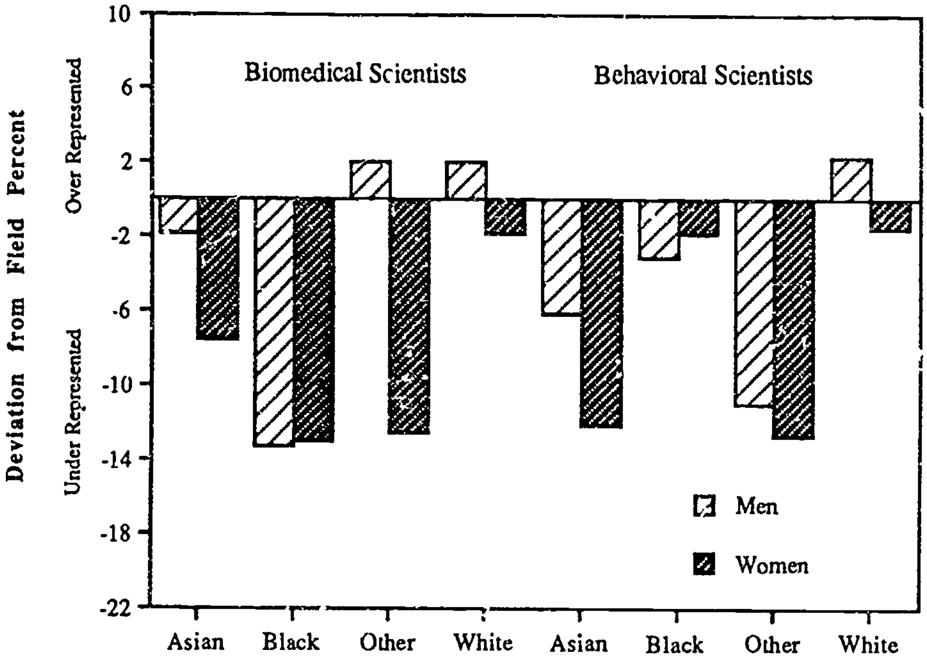
[22]For details, see *NIH Guide for Grants and Contracts, Special Issue: Initiatives for Underrepresented Minorities in Biomedical Research*, vol. 18, no. 14, April 21, 1989.

[23]There are indications that minorities in the life sciences are receiving federal support from all sources at rates comparable to other groups. Those indicating primary support from any federal source were 23.8 percent overall, 20.0 percent for American Indians, 43.7 percent for Asians, 31.3 percent for blacks, 29.5 percent for Hispanics, and 26.9 percent for whites. See National Research Council, *Summary Report 1988: Doctorate Recipients From United States Universities*, Washington, D.C.: National Academy Press, 1989, Table L.



SOURCE: Appendix Table A-13.

Figure 2-15. Under- and over-representation of race/sex groups in reporting definite postdoctoral plans of biomedical (field percent = 88.5) and behavioral (field percent = 79.2) doctoral recipients, 1983-1987.

larger fraction of whites report definite plans than do minorities; and in all categories other than black, fewer women than men report definite career plans.

The committee believes that the data in Figures 2-14 and 2-15 are indicative of inadequate mentoring at the predoctoral level: role models for women and minorities are too few in number, and contacts with faculty may be too sparse to provide needed guidance in seeking NIH support in graduate school and in career planning. These factors are very likely compounded with others, such as inadequate precollege preparation. Whatever the specific mix of causes, the committee interprets the data as suggesting a clear need for future research and appropriate action.

These patterns in degree awards are having predictable time-lagged effects on the composition of the biomedical and behavioral labor force. The data in Table 2-1 reflect an average annual growth rate of about 4.7 percent in the size of the total labor force between 1977 and 1987. During that time period, the percentage of women in both doctoral fields grew substantially, to more than 20 percent of the biomedical work force and more than one-third of the behavioral scientists. The average annual growth in the numbers of white females were 7.7 and 8.3 percent, respectively; these rates of increase were shared by nonwhite women and, to a lesser extent, by minority males. The only groups growing at less than these rates were white males, whose numbers increased by only 3.6 and 2.9 percent in the biomedical and behavioral fields, respectively.

TABLE 2-1: Doctoral Biomedical and Behavioral Labor Force, by Sex and Race, 1977 and 1987

		Biomedical		Behavioral	
		1977	1987	1977	1987
MEN	Asian	4.83	6.95	1.04	1.20
	Black	1.00	1.01	0.78	1.14
	Other	1.06	1.21	0.82	1.32
	White	77.27	69.25	73.39	61.91
WOMEN	Asian	1.28	2.04	0.35	0.65
	Black	0.25	0.40	0.54	1.06
	Other	0.15	0.35	0.22	0.69
	White	14.16	18.78	22.86	32.03
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	Total (a)	100.00	100.00	100.00	100.00
	Number	53,037	84,045	41,238	65,170

a/ Excludes those who are retired or not reporting.

SOURCE: NRC, Survey of Doctorate Recipients.

Women nevertheless appear to be underrepresented in a basic outcome of receiving a doctorate in biomedical or behavioral science: full-time employment as a scientist.[24] In 1987 more than 90 percent of the biomedical and 85 percent of the behavioral scientists were so employed; of the remainder, about half were employed part-time (mostly in science); 38 percent were unemployed; and 23.1 percent were unemployed but not seeking a position. Figure 2-16 dramatizes the disproportionately low percentage of eligible women employed full-time in scientific work: 18.4 percent of all women biomedical Ph.D.s in 1987 were not doing full-time science, but this is down from nearly a quarter in 1977. Race, however, was an insignificant factor in determining participation rates in full-time biomedical science. The situation is similar for the behavioral sciences.

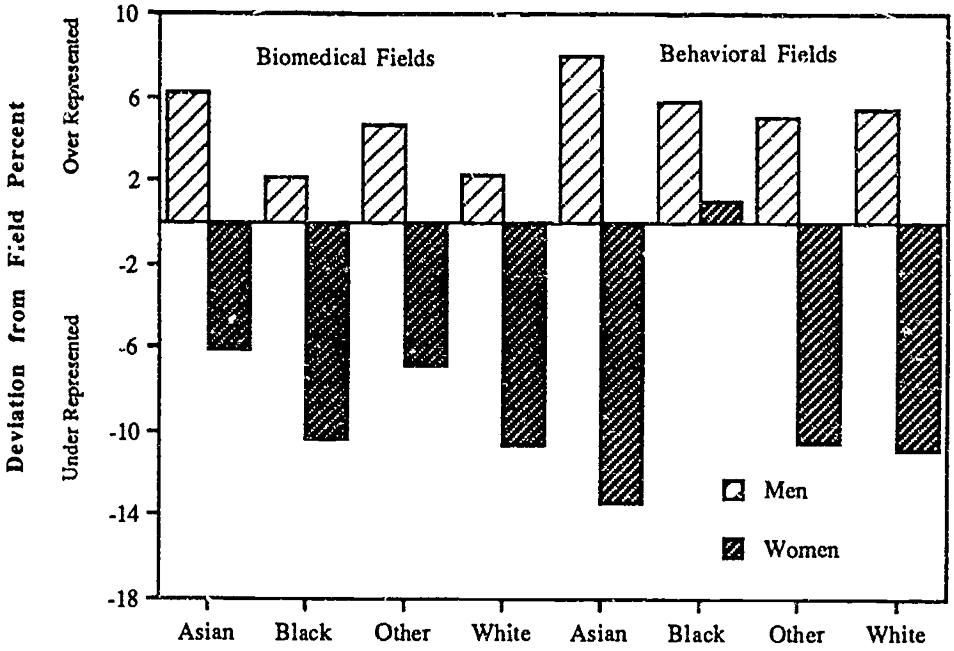
These data have clear, important implications for science policymakers. If the fraction of biomedical and behavioral science Ph.D.s not doing science full-time remains in excess of 15 percent, and if the fraction of degrees awarded to women continues to increase, the projected personnel shortage will be exacerbated (see Chapter 3).

Citizenship

Although U.S. science has long relied on the contributions of immigrants, the increasing number of foreign graduate students requires that the role of foreign students and immigration be included in any assessment of the adequacy of the supply of biomedical and behavioral scientists in the United States.

In 1988 foreign students earned 18.1 percent of the doctorates in biological sciences awarded by U.S. institutions, up from 11.8 percent in 1980. In the behavioral sciences the proportion earned by foreign students was less: 7.3 percent in 1988, up from 6.1 percent in 1980. Foreign students who are permanent residents at the time they earn their doctorates

[24]Another normal outcome, in the biomedical sciences at least, is that of postdoctoral study. Those reporting current postdoctoral study are eliminated from the denominators of percentages reported in Figure 2-16 and the corresponding appendix table.



SOURCE: Appendix Table A-15.

Figure 2-16. Under- and over-representation of race/sex groups in full-time employment in the S&E labor force of biomedical (field percent = 92.3) and behavioral (field percent = 85.6) scientists, 1987.

behave very much like U.S. citizens. For example, they virtually all stay in the United States to work.[25] During the 1980s, however, about 74 percent of the foreign degree recipients in the biological sciences and about 65 percent in the behavioral sciences were, at graduation, temporary reside..ts who behave very differently from U.S. citizens: only about one-fourth of the temporary residents we,e still in the United States working or doing postdoctoral study 1-2 years after graduation. Furthermore, evidence shows that foreign nationals who enter the U.S. work force tend to emigrate from the United States at a fastcr rate than persons who were U.S. citizens at the time of receiving the doctorate. In the life sciences and the social/behavioral sciences, consequently, foreign recipients of U.S. doctorates comprise a comparatively small part of the increases in the doctoral work force--approximately 6 and 4 percent, respectively--in contrast to engineering, where they contribute 37 percent of the growth.[26]

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[25]If we consider all foreign degree recipients, the proportion staying here to ork goes up to about 40 percent. See Michael G. Finn, *Foreign National Scientists and Engineers in the U.S. Labor Force, 1972-1982*, Oak Ridge, TN: Oak Ridge Associated Universities, 1985.

[26]Michael G. Finn and Sheldon B. Clark, *Estimating Emigration of the Foreign-Born Scientists and Engineers in the United States*, Oak Ridge, TN: Oak Ridge Associated Universities, 1988.

CHAPTER 3

THE FUTURE LABOR MARKET FOR BIOMEDICAL AND BEHAVIORAL RESEARCH PERSONNEL

OVERVIEW

Labor market projections for this report were expanded to include demand from industry, government, and other nonacademic sources. Labor demand projections reflect increased attrition due to the aging of the work force. The model has also been refined in its reflection of the various segments of the market for biomedical and behavioral scientists. Finally, the committee attempted to extend its projections to the year 2000.

For biomedical scientists, the projected current Ph.D. production is inadequate to meet growing demand. Employment growth is driven by industry, which may become the largest employer by 1995. Jobs in R&D increase more rapidly than in non-R&D. Because of demand growth and higher attrition, Ph.D. production must increase.

For behavioral scientists, the labor market should remain in approximate balance. Growing demand for clinical psychologists may draw behavioral Ph.D.s out of R&D. The market for nonclinical psychologists is projected to be in approximate balance in the 1990s, and the model indicates a stable market for other behavioral scientists--anthropologists, sociologists, audiologists, and speech pathologists.

The labor market for physician/scientists is more difficult to project. Recent studies indicate that the demand for clinical investigators has been overstated in the past. However, a number of factors suggest that the demand for well trained physician/scientists will increase in the future.

Extended projections to the year 2000 reflect similar trends. Demand for biomedical scientists could be twice the current level of biomedical Ph.D. production. The market for behavioral scientists is in better balance with supply unless growth is higher than expected. The demand for physician/scientists could grow substantially, particularly if significant numbers of M.D.s are drawn into basic research in the biomedical sciences.

PRIOR COMMITTEE PROJECTIONS AND CURRENT METHODOLOGY

The legislation mandating this study requires the committee to assess "the nation's overall need for biomedical and behavioral research personnel."[1] Past committees have defined this "need" in labor market terms--that is, how many biomedical and behavioral researchers will be "needed" in the future to fill academic demand?

Job openings were determined by growth in the number of academic positions and faculty attrition. These projections were developed for the near term; the 1985 committee report included projections to 1990. This report expands the earlier analysis in several ways:

1. In almost every biomedical and behavioral field, the major source of historical and projected employment growth is in nonacademic sectors,

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[1]Section 489 of P.L. 99-158.

primarily private industry. This report expands the labor market analysis to include industry, government, hospital, and other nonacademic sources of labor demand for biomedical and behavioral scientists.[2]

2. This analysis develops separate projections for the labor market in general and for that subsection of the labor market associated with scientists whose primary work activity is R&D or the management of R&D.

3. Given concern over the graying of the work force, the current analysis includes a demographic/economic model for estimating scientist attrition due to death, retirement, and net occupational movement. Attrition in this model is a function of the age and experience structure of the scientist work force.

4. The analysis brings labor supply into the labor market assessment. This was not done in earlier reports.

5. Given that the median time to complete a biomedical Ph.D. has grown from seven years in the late 1970s to eight years in 1987, the 1997 biomedical scientist labor market will be influenced by student decisions and NRSA policy in 1989. In the behavioral sciences, median time to Ph.D. has increased from approximately 8.5 years to 10.5 years during the same period. These time lags argue for a longer horizon of analysis. Consequently, the current study projects labor market variables to the year 2000.[3]

THE MODEL

Figure 3-1 is a schematic drawing of the labor market assessment model used in this report.[4] The stock of scientists in time period t is characterized by biological age (years since birth) and career age (years since degree). Historical data provide estimates of the deaths and retirements by biological age; these scientists are removed from the stock. Those who do not retire or die can also leave the field for other employment; this too is

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[2]Although the NRSA program is concerned only with research personnel, it is necessary to take account of the total demand for biomedical and behavioral scientists to ensure that an adequate supply is available. Rapid employment growth in the industrial sector could create hiring difficulties in the academic sector even if academic sector employment is stable or declining.

[3]Despite the more secular nature of the model, it is unlikely that shifting demographics will substantially affect the analysis. The National Center for Education Statistics' (NCES) demographic model projections indicate that M.D.s and first-professional degrees will "increase slightly or remain stable" through 1998. NCES also projects college enrollments to decline from 12.56 million in 1988 to 12.17 million in 1998 (midcase). These points indicate that demographics will not have major influences on supply of Ph.D.s or demand for faculty during the projection period. See NCES, *Projection of Education Statistics to 1997-1998*, Washington, D.C.: U.S. Government Printing Office, 1988.

[4]For a more complete discussion of the labor market assessment model, see Joe G. Baker, "Biomedical/Behavioral Cohort Model: A Technical Paper," in Volume III of this report.

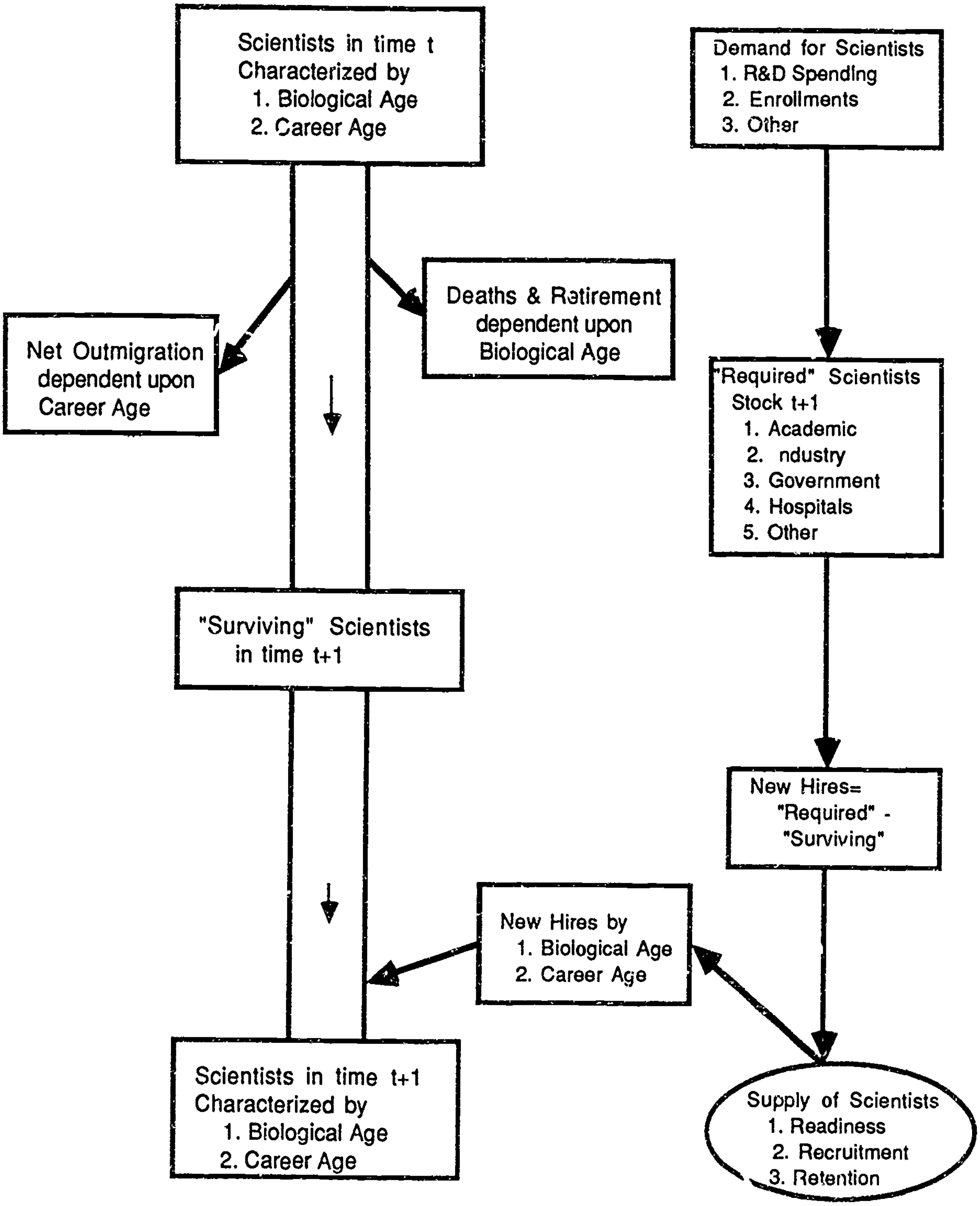

Figure 3-1. Labor market assessment model.

assumed to be a function of career age.[5] Estimates of migration presented here are net (outmigration less inmigration from other fields) and are estimated from historical data. The surviving scientist stock is available for employment in period $t+1$.

The required scientist stock in period $t+1$ is estimated from submodels that link demand for scientists to the demand for the goods and services that scientists produce (e.g., conducting R&D or training graduate students). The submodels were constructed from demand equations that were estimated from historical data. For example, non-R&D biomedical industrial employment was estimated to be a function of real constant dollar output of the pharmaceutical industry; R&D biomedical industrial employment was estimated to be a function of real constant dollar, private sector, health-related R&D spending. These demand submodels vary by discipline (biomedical, behavioral, clinical), sector (academic, industrial, government, etc.), and activity (R&D, non-R&D).

The difference between the surviving scientist stock and the required scientist stock in period $t+1$ represents the number of job openings that must be filled by new entrants. These job openings are compared to supply to compute "vacancy ratios," (i.e., the number of job openings per new Ph.D.). Increases or decreases in future vacancy ratios from historical ratios give one a sense of changes in the projected demand/supply balance in the scientist labor market. This same basic analysis is replicated for the R&D subsector by comparing R&D job openings to postdoctoral "graduates."

Obviously, the number of job openings is dependent upon a wide range of other variables, including health R&D expenditures, general economic growth, wage rates, and other labor market factors. Likewise, decisions to enroll in graduate school are based in part on current student support, starting salaries, expected future earnings, earnings available in alternative careers, and other factors. In the simplified approach used here, however, we have implicitly assumed that these excluded variables are constant; we are primarily concerned with major shifts in the demand and supply of scientists through time. While the resulting analysis takes little account of the responses of institutions and individuals to changing labor market conditions, the projections contained in this chapter do serve to highlight the consequences of current trends and suggest courses of corrective action.[6] Where possible, we do discuss potential labor market adjustments to changing conditions.

THE FUTURE LABOR MARKET FOR BIOMEDICAL SCIENTISTS

The demand for biomedical scientists is derived from demand for the goods and services they produce, primarily biomedical research and instruction. In order to estimate the future need for biomedical scientists, we must estimate the level of demand for these goods and services, e.g., the level of health-related R&D to be conducted and the levels of undergraduate and graduate enrollment. Massive new public health efforts in areas such as AIDS research could increase the demand for health research personnel significantly.

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[5]This is based upon the assumption that there is a "career pattern" of outmobility based upon years since Ph.D. (e.g., the probability that one would leave his/her degree field for other employment is small immediately after receipt of the degree; but in later years scientists may move into management and administration). The reader is referred to the current labor market section for estimates of these outmigration rates.

[6]An econometric approach to projecting the biomedical scientist labor market that included prices and feedback mechanisms produced results consistent with this chapter. See Joe G. Baker, "The Ph.D. Supply Crisis: A Look at the Biomedical Sciences," paper given at the Western Economics Association Meetings, Lake Tahoe, Nevada, July 21, 1989.

Private sector research, especially in the emerging biotechnology industry, has the potential to command an increasing portion of limited biomedical scientific resources. Demand for teaching faculty is dependent upon the enrollment levels in graduate programs as well as on university R&D. As the biomedical scientist cadre matures, attrition from death and retirement will increase the demand for replacement in these areas.

Growth in Employment

In order to provide projections of future demand for biomedical scientists, the committee developed the following scenarios, which are summarized in Table 3-1:

1. *Low Case*: The low-case scenario corresponds to a conservative retrenchment from current trends: cuts are imposed on growth rates of federal health R&D, and the private sector retreats from current growth levels. In this scenario, both federal and private health-related R&D slow to approximately half their current rates of growth. Graduate and undergraduate enrollment in biomedical sciences decline by 1 percent annually.

2. *Mid Case*: The mid-case scenario is largely "status quo" with regards to both federal and private health- related R&D funding. Enrollments are assumed to be stable at 1987 levels.

3. *High Case*: The high-case scenario is based on large increases in health-related R&D funding in such areas as AIDS and alcohol and drug addiction. Private sector efforts in biotechnology and other areas exceed historical levels. Enrollments are assumed to grow by 1 percent annually.

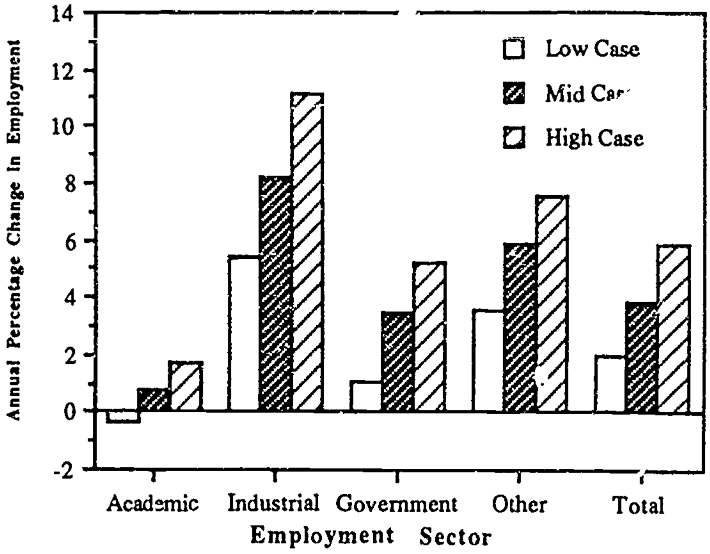
TABLE 3-1. Projection Model Assumptions, Biomedical Sciences

	Historical Annual Growth Rate			Assumptions for Future Annual Growth Rate		
Variable	10 Year	5 Year	1 Year	Low	Mid	High
Real Health R&D Expenditures						
Federal	2.7%	5.4%	7.3%	1.5%	2.7%	4.0%
Private	9.3%	10.3%	9.6%	5.0%	9.0%	13.0%
Other	6.2%	8.8%	-1.1%	2.0%	3.0%	4.0%
Enrollment in Universities	-0.3%	-0.2%	-0.3%	-1.0%	0.0%	1.0%
New Ph.D.s	1.4%	0.0%	2.7%	-1.0%	0.0%	1.0%

SOURCE: Volume II, Tables B1, B3, and B8. Projection assumptions developed by the committee.

Projections of the required stock of scientists (Figure 3-1) were developed using these assumptions in the labor demand submodels. Figure 3-2 details the results of these projections. Regardless of the scenario chosen, the same basic trend is evident: industrial employment of biomedical scientists dominates growth in the future labor market, and in

all but the low case it becomes the largest employment sector by the year 1995. Historical growth in biomedical employment averaged 4.8 percent annually for the 1973-1987 period; the projected growth rates for the low, mid, and high cases are 1.8 percent, 3.6 percent, and 5.2 percent, respectively. Biomedical scientists engaged primarily in R&D or the management of R&D will grow faster than the biomedical work force in general. This is because private industry, in which a high percent of biomedical scientists are engaged in R&D, is projected to grow faster than the other employment sectors.

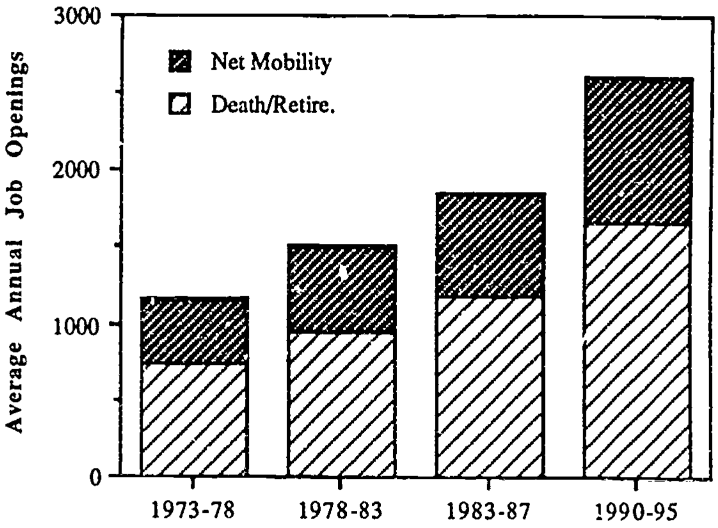


SOURCE: Appendix Table A-18.

Figure 3-2. Projected annual growth rates for biomedical scientists, 1987-1995.

Attrition

Job openings are also created by death, retirement, and outmobility. Given the graying of the scientific work force, these openings are expected to increase in the future.[7] Figure 3-3 portrays the estimated number of openings from death, retirement, and net outmobility for historical and projected periods (mid-case scenario). Openings due to death and retirement are projected to increase from approximately 1,200 per year in the latter 1980s to 1,650 per year for the 1987-1995 period. Net worker mobility, which created approximately 650 job openings annually in the 1980s, is projected to increase to 950 per year for the 1987-1995 period. For the 1987-1995 period, therefore, approximately 2,600 new scientists will be required annually just to maintain *current* employment levels. This



SOURCE: Appendix Table A-8.

Figure 3-3. Historical and projected biomedical scientist attrition, 1973-1995.

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[7]In 1987, approximately 10,800 employed biomedical scientists were aged 55 or older. Under the mid-case scenario, this will grow to approximately 15,500 in 1995. See Joe G. Baker, "Biomedical/Behavioral Cohort Model: A Technical Paper," in Volume III of this report.

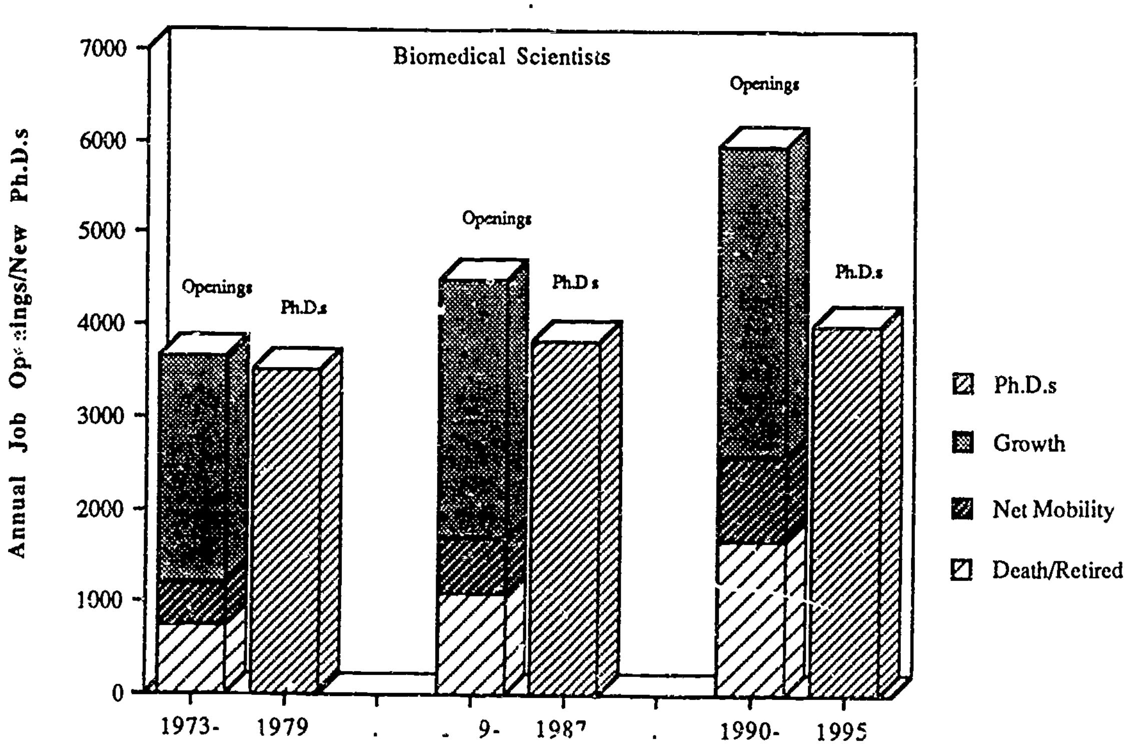
figure will rise to approximately 3,400 by the year 2000. Given that about 4,000 Ph.D.s are awarded currently, growth in employment can occur only if the number of Ph.D.s increases.

Future Demand and Supply

The sum of openings due to attrition and growth is the total number of "new hires" required annually (Figure 3-1). Figure 3-4 compares the projected labor demand (job openings) to labor supply (new biomedical Ph.D.s). It shows that the number of positions per new biomedical Ph.D. has grown during the 1980s over the 1970s. Assuming that degree production changes in proportion to enrollments (-1, 0, and 1 percent growth for the three scenarios), both the mid-case and high-case scenarios will produce even greater imbalances between job openings and new biomedical Ph.D.s.

In summary, the committee projects a future labor market for biomedical scientists that is characterized by increasing imbalance between demand and supply. Because death and retirement are expected to double in the next decade, and because most of the openings created by retirement will be in academe, this presages a time of unprecedented competition between academic institutions and the emerging biotechnology industry. This situation can be avoided by some combination of the following factors:

- *Decreased growth*: Current biomedical Ph.D. production could support future demand if future growth is in the neighborhood of 2 percent annually. However, this is a considerable decrease from the 4.8 percent historical growth rate in biomedical Ph.D. employment.



SOURCE: Appendix Table A-19.

Figure 3-4. Average annual biomedical job openings and new Ph.D.s, 1973-1995.

- *Increased production*: Biomedical Ph.D. production could support faster growth if the number of degrees increases from the current level of 4,000 per year to the 5,000-6,000 range. Given current trends in first-year graduate enrollments in biomedical sciences, however, there is likely to be no major increase in Ph.D. production until the mid-1990s.[8]

- *Decreasing graduate school attrition and time to degree*: The high rates of graduate student attrition and lengthy time to degree increase the sluggishness and decrease the productivity of graduate schools in the production of new scientists. Little is known about the causes of these problems; therefore it is difficult to offer solutions other than more research. If time to the doctorate and attrition could be reduced, however, the benefits would be more immediate than increasing enrollments.

- *Increased retention of women*: Female scientists have much higher dropout rates than men (see Chapter 2). If programs were developed to increase full-time science participation by females who hold Ph.D.s, effective labor supply would increase.

- *Recruitment of outside Ph.D.s*: Inmobility of Ph.D.s from other fields could increase. Recruiting new entrants from other fields is viable so long as there are people in other fields to draw on. However, most studies of the science and engineering labor market in the 1990s project a similar imbalance between new Ph.D.s and job openings in other fields. Therefore, it may become increasingly difficult to draw entrants from other fields. Also, these entrants may not be as productive as scientists with degrees in biomedical sciences, and there may be other costs associated with hiring them, such as training costs or increased supervision requirements. Very little is known about these tradeoffs, however.

- *Decreased attrition*: Patterns of outmobility and retirement could change; perhaps incentives could be developed to affect this behavior such as rewarding delayed retirement.

- *Recruitment of foreign Ph.D.s*: Foreign nationals with permanent visas could help meet U.S. science need.

THE FUTURE LABOR MARKET FOR BEHAVIORAL SCIENTISTS

The behavioral sciences are made up of a group of disciplines that includes clinical psychology, nonclinical psychology, anthropology, sociology, and speech pathology (these latter three are grouped together as "other behavioral sciences"). Clinical psychologists are mainly involved in patient care; the behavioral science disciplines that are R&D-oriented are nonclinical psychology and other behavioral sciences.

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[8]If one assumes that biomedical Ph.D. output will change in parallel with lagged first-year biomedical graduate enrollment change, one can estimate Ph.D. labor supply through 1995 based upon current enrollment, although historically such a model yields a poor fit. Using this assumption does not substantially change the results, however: the lagged enrollment model shows Ph.D. output in the biomedical sciences increasing very slowly, from 4,000 in 1987 to only 4,100 in 1995. See Joe G. Baker, "The Ph.D. Supply Crisis: A Look at the Biomedical Sciences."

The future labor market for clinical psychologists is projected to be characterized by increasing imbalance of demand over supply. Given that most of this growth is practice-related, the direct consequences for behavioral science research personnel are slight. However, clinical practice will offer an attractive employment opportunity for behavioral scientists in general, and could be expected to draw scientists from R&D activities.[9]

Nonclinical Psychology

Nonclinical psychologists make up approximately 30 percent of the behavioral scientist work force. Unlike clinical psychologists, their work consists largely of teaching and research. Over 80 percent of nonclinical psychologists work in private industry or academic settings; the remaining 20 percent are distributed among government, hospitals, and other employment sectors.

The key assumptions employed for projecting future lev'ls of demand for nonclinical psychologists appear in Table 3-2 and are summarized here:

- o Graduate enrollment growth in the behavioral sciences is modest or negative under three scenarios: low case (-1.0 percent annually), mid case (0.0 percent), and high case (1.0 perce).

TABLE 3-2. Projection Model Assumptions, Behavioral Sciences

	Historical Annual Growth Rate			Assumptions for Future Annual Growth Rate		
Variable	10 Year	5 Year	1 Year	Low	Mid	High
Graduate Enrollment in Universities	1.1%	0.2%	-0.3%	-1.0%	0.0%	1.0%
Industrial Employment of Nonclinical Psychologists	6.6%	3.7%	3.2%	2.0%	3.0%	4.0%
Nonacademic employment of Other Behavioral Scientists						
R&D	3.5%	-2.2%	38.9%	3.0%	5.0%	7.0%
NonR&D	14.4%	15.7%	-2.0%	7.0%	10.0%	15.0%
New Ph.D.s	-0.7%	-1.1%	-1.8%	-1.0%	0.0%	1.0%

SOURCE: Volume II, Tables C1, C10-1, and Table A-10 from Joe G. Baker, "Biomedical Cohort Model: A Technical Paper" in Volume III of this report. Projection assumptions developed by the committee.

[9] In 1987 about 20 percent of employed clinical psychologists had degrees in oth elds. However, future movement into the field may be slowed by changes in state certification requirements.

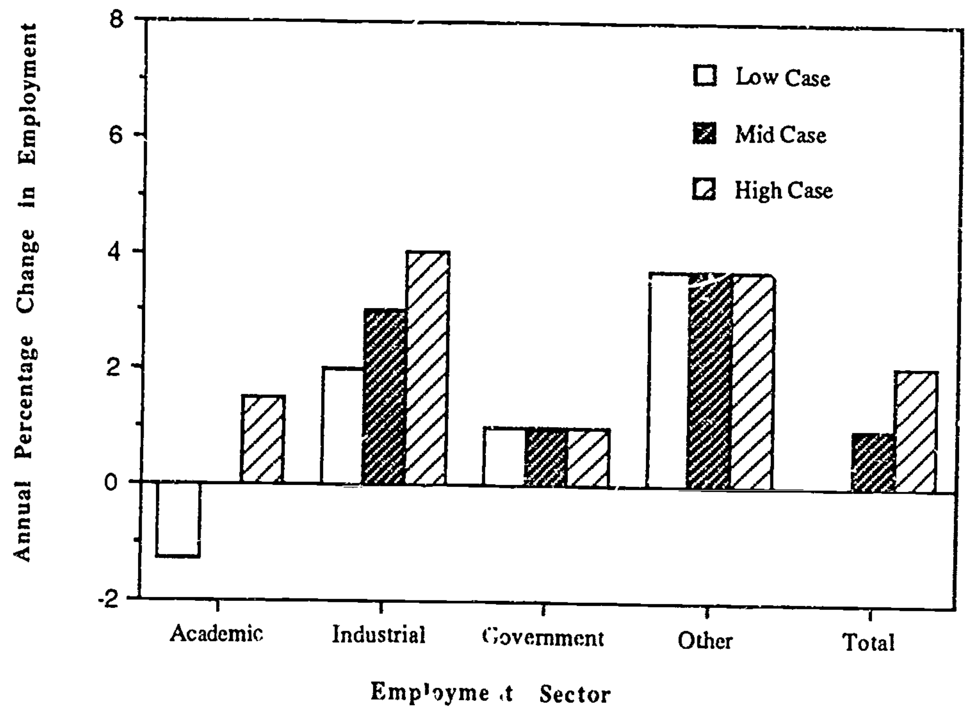
- o Demand growth for nonclinical psychologists in industry continues to grow under the low case (2.0 percent per year), mid case (3.0 percent), and high case (4.0 percent). This compares to an historical growth rate of 3.1 percent per year for the 1985-1987 period.

- o Growth in demand for nonclinical psychologists in the government sector is assumed to be 1 percent annually in each scenario.

Figure 3-5 displays the resulting projections. Total growth in the employment of nonclinical psychologists averaged 3.1 percent annually for the 1973-1987 period; projected employment growth is expected to range from -0.4 percent to 1.9 percent. In all cases nonclinical psychologists engaged primarily in R&D or the management of R&D are projected to remain at a fairly constant proportion (approximately 27 percent) of the total behavioral scientist work force.

Figure 3-6 shows the historical and projected trends in the number of annual openings from death, retirement, and outmobility. Total annual attrition increased from approximately 660 openings in the early 1970s (230 death and retirement and 430 net outmobility) to approximately 1,000 in the late 1980s (430 death and retirement and 570 net outmobility). This level of annual attrition is projected to increase only slightly, to approximately 1,050, for the 1990-1995 period under the mid-case scenario.

As shown in Figure 3-7, the number of job openings per new nonclinical psychology Ph.D. has been between 0.8 to 0.9 for the 1973-1987 period. Assuming degree production changes in parallel with enrollments (-1, 0, and +1 percent annual change for the three scenarios), there will be little change from these vacancy ratios in the 1990s. Even the

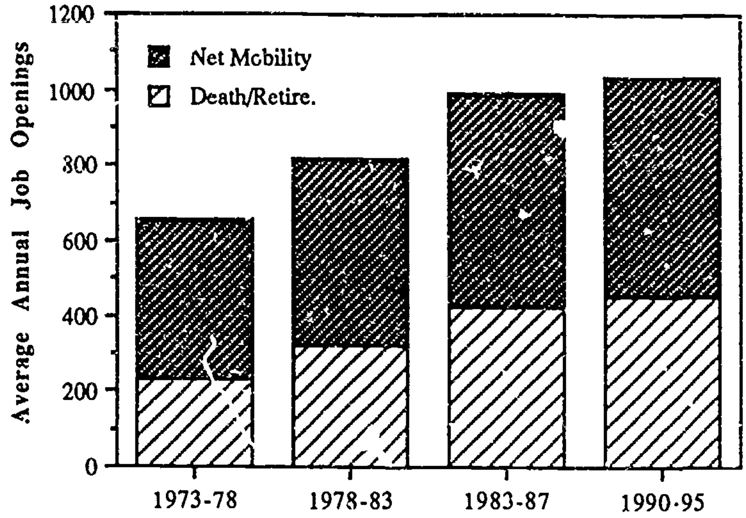


SOURCE: Appendix Table A-20.

Figure 3-5. Annual growth rates for nonclinical psychologists, 1987-1995.

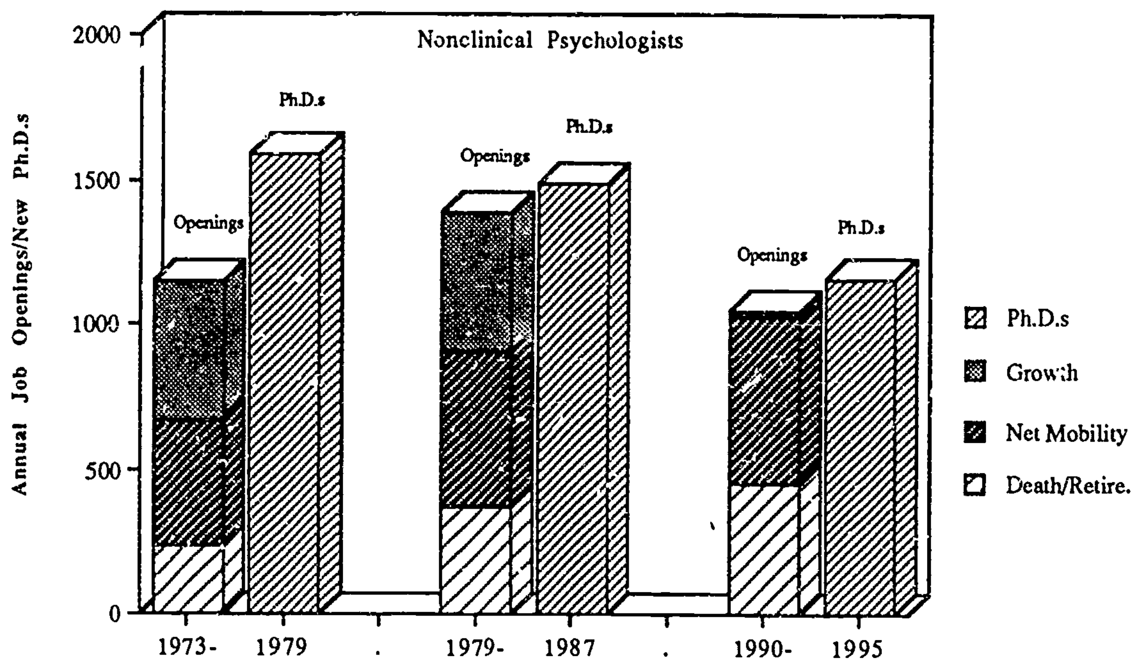
high-case scenario projects approximately one job opening per new nonclinical psychology Ph.D. Taken together, Figures 3-5 through 3-7 show that the labor market for nonclinical psychologists moved from excess supply in the 1970s to approximate balance in the 1980s. This balance is projected to continue into the 1990s, with approximately 80 percent of all job openings coming from attrition.

Projections for nonclinical psychology R&D employment indicate a softening of the job market, with fewer R&D job openings per postdoctorate through 1995 than



SOURCE: Appendix Table A-9.

Figure 3-6. Historical and projected average annual attrition for nonclinical psychologists, 1987-1995.



SOURCE: Appendix Table A-21.

Figure 3-7. Annual average job openings and new Ph.D.s in nonclinical psychology, 1973-1995.

during the 1973-1987 period, assuming that postdoctorate production remains near its 1987 levels.

In summary, the future labor market for nonclinical psychologists will be characterized by approximate balance unless (1) future rates of growth in employment exceed the high-case scenario rate of 1.9 percent annually; (2) the award of doctoral degrees declines substantially (by approximately 3.0 percent per year) from its current level; and/or (3) the clinical psychology market captures a larger share of nonclinical psychologists. The potential for demand (job openings) in excess of supply (new nonclinical psychology Ph.D.s) is even greater in the late 1990s (see "Prospects for the Long Term," below).

Other Behavioral Scientists

Other behavioral scientists include Ph.D.s in anthropology, sociology, audiology, and speech pathology. In 1987 other behavioral scientists made up about one in five behavioral scientists. The "other" group is dominated by academic employment: almost 85 percent of total employment is in academic work, with the remaining 15 percent scattered across the other employment sectors.

Given the predominance of academic work, future employment will be closely linked to academic demand. The assumptions used to project future employment, shown in Table 3-2, are as follows.

- Annual growth in graduate enrollment remains modest in all three scenarios: low case (-1.0 percent per year), medium case (0.0 percent), and high case (1.0 percent). As a result, academic employment of "others" grows very little.

- Employment of "others" in nonacademic employment sectors grows more rapidly. The low-, medium-, and high-case growth rates are 7, 10, and 15 percent annually for non-R&D scientists, respectively, and 3, 5, and 7 percent annually for scientists engaged in R&D or the management of R&D.

Figure 3-8 displays the resulting projections. Total growth in the employment of other behavioral scientists averaged 4.8 percent annually for the 1973-1987 period. Projected growth of employment ranges from -0.3 percent to 3.4 percent. In all but the low case, employment in R&D or the management of R&D grows more slowly than non-R&D employment. Attrition is projected to grow to approximately 700 per year for the 1987-1995 period (300 death and retirement, 400 net mobility) from about 650 in the late 1980s. The number of job openings available to each new "other" Ph.D., which had been approximately 0.9 for the 1973-1987 period, would increase only under the high-case scenario. R&D vacancy ratios through 1995 show little change from current values.

In summary, the future labor market for other behavioral scientists will be characterized by relative stability unless (1) the future rate of growth in employment exceeds 2.0 percent annually; and/or (2) degree production decreases from its current level of 950 annually to less than 700 annually.[10] If time to the doctorate in the behavioral

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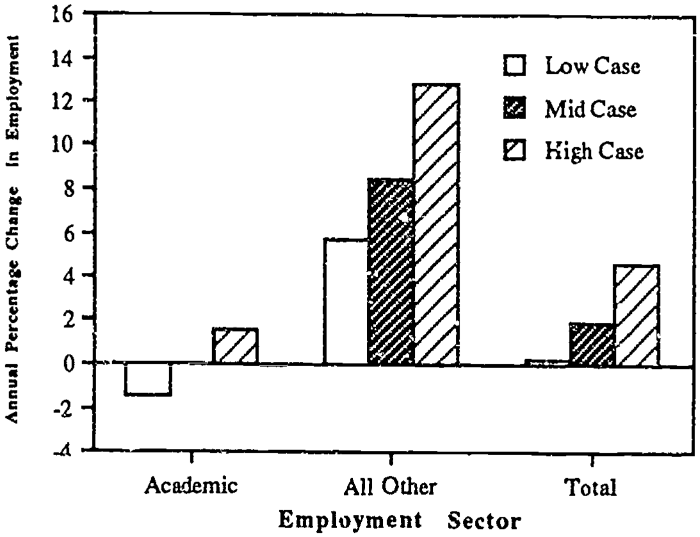
[10]This assumes that degree production changes proportionately with enrollments. First-year graduate enrollments in other behavioral sciences have fallen, from 4,470 in 1980 to 3,995 in 198 Although the relationship between first-year enrollments and lagged Ph.D. production is poor, these declines could translate into lower Ph.D. output during the 1990s. If this occurs, a portion of this supply shortfall could be absorbed by increasing faculty productivity: in 1975, 5.4 B.A./B.S. degrees in other behavioral sciences were awarded per faculty member; in 1987 this statistic had fallen to 1.6.

sciences continues to grow, degree production could decrease. A combination of these events could also produce a market imbalance. In the R&D sector, movement of postdoctoral students into the labor market at the current level of approximately 120 annually would satisfy long-term R&D demand.

The committee's projections of greater growth in demand for biomedical than for behavioral scientists disagrees with the findings of a recent study by Bowen and Sosa. They examined the prospects for arts and sciences faculty and concluded that impending shortages would be greater in the social sciences and humanities than in the natural sciences.[11] One reason for this disagreement is the fact that this report focuses on research personnel and thus excludes the fastest-growing area of the behavioral sciences--clinical psychology. Another is that they make assumptions about changes in student values that our committee did not make.[12]



SOURCE: Appendix Table A-22.

Figure 3-8. Projected annual growth rates for other behavioral scientists, 1987-1995.

THE FUTURE LABOR MARKET FOR PHYSICIAN/SCIENTISTS

Demand for Clinical Investigators

Estimating the demand for clinical investigators would be a difficult task in the best of circumstances. Terms such as "scientist," "investigator," and "research" are poorly defined and frequently misapplied. Past reports and projections by this committee have taken a similar misstep by virtue of equating "clinical faculty" and "clinical investigators." More recent evidence indicates that the demand for clinical investigators may be lower than previously estimated.

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[11]William G. Bowen and Julie Ann Sosa, *Prospects for Faculty in the Arts and Sciences: A Study of Factors Affecting Demand and Supply, 1987-2012*, Princeton, NJ: Princeton University Press, 198?.

[12]Other relevant differences are that Bowen and Sosa focus on faculty and do not explicitly take account of research. They also use a proportional assumption concerning faculty and enrollment that we consider to be unrealistic: in their baseline case, they find a tighter market as the number of college-aged students stops declining and then begins to increase.

The American Association of Medical Colleges (AAMC) Faculty Roster indicates that 69.6 percent of academic physicians are engaged in research activity, but several studies have concluded that this significantly overstates the number of medical school physician faculty involved in research.[13] Levey, et al., analyzed surveys of faculty in research-intensive clinical departments (internal medicine) and arrived at a figure of 34 percent, later revised (using stricter criteria) to 20 percent. Sherman's reexamination of the same data yielded a *median* R&D effort of 25 percent. Institute of Medicine data, based on seven-day diaries of 3,400 faculty members in 20 schools of medicine and more than 100 teaching hospitals taken in the spring of 1975, indicated that 20 percent were involved in research, either alone or in combination with teaching and patient care; this survey did not include R&D administration as a specific reported item. It seems reasonable, based on these studies, to assume that 20-25 percent of all clinical faculty members would be properly classified as clinical investigators. This places the demand for physician/scientists in medical schools at between 10,000 and 12,000; the total demand would be something on the order of 16,000 to 18,000 (10,000 to 12,000 medical school, 434 NIH, and 5,651 other).

Similar numbers can be arrived at by extrapolating from the NIH-documented population of clinical investigators. Their numbers have increased by 50 percent in the last 17 years, from 4,300 in 1970 to 6,400 in 1987, or roughly 2.4 percent per year. This figure would represent a lower boundary on the number of academically-based research M.D.s. Assuming that the ratio of M.D. grantees to total M.D. investigators is the same as that for Ph.D. investigators--15,589 grantees out of 22,751 Ph.D.s in academic R&D--then by analogy there would be 9,330 M.D.s engaged in academic R&D. Because patient-related research is poorly supported by NIH, the figure is probably somewhat higher, plausibly in the 10,000 to 12,000 range suggested above.

New research efforts requiring M.D. training would increase these demand figures to some unknown extent. New, well-funded initiatives in such areas as health services research, outcome assessment, and epidemiology, in both academic and industrial settings, plus renewed interest in occupational and environmental health, would require additional M.D. participation in areas where medical training has traditionally given little emphasis.

All of this suggests that the time has come to take a new look at the clinical investigator demand model, particularly the demand equations, and to develop a more accurate model on a more rational basis. For example, almost 50 percent of medical school revenues now come from patient care sources; this is hardly an indicator of demand for clinical investigators. Medical student enrollment has leveled off, but the mix of faculty effort may be more directly influenced by house staff and fellow enrollments. The clinical scientist employment reported by NIH appears low--where, for example, are Veterans Administration (VA), Food and Drug Administration (FDA), and other federally-employed investigators reported? To reflect how the demand for clinical investigators is created, and how decisions to employ them are made would require a model in which demand is expressed as an explicit function of such variables as NIH intramural and extramural budgets, FDA budget, pharmaceutical industry R&D expenditures, and state research appropriations to medical schools.

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[13]See G. S. Levey, et al., "Postdoctoral Research Training of Full-Time Faculty in Academic Departments of Medicine," *Annals of Internal Medicine*, vol. 109, no. 5 (September 1988), pp. 414-418; Charles R. Sherman, "The NIH Role in Training of Individual Physician Faculty: A Supplementary Analysis," NIH memorandum dated March 30, 1989; and Institute of Medicine, *Medicare and Medicaid Reimbursement Policies Study*, Washington, D.C.: National Academy Press, 1976.

The Supply of Clinical Investigators

There is no reason to assume that the number of M.D.s available for clinical investigation will increase because of an oversupply of physicians who find patient care less satisfying for reasons of economics, competition, and/or personal preference. For example, the demand for M.D.s in the health care system's bureaucracy is not trivial, and many physicians may decide to become health care executives or take other career paths that have little or nothing to do with their training as M.D.s. Also, in spite of their best efforts, some of them may not have the intellectual wherewithal, imagination, and drive required to compete in the world of clinical investigation. For all of these reasons, it is not logical to assume that research is more attractive than patient care, nor is there any basis to assume a reduction in the research attrition rate.

The current supply model arbitrarily sets a fraction of the total physician manpower supply as the supply of clinical investigators--a procedure that is simplistic to an unsatisfactory degree. Supply also bears some relationship to the students' responses in the AAMC surveys regarding their future intentions, to the proportions that select subspecialty research training, and most importantly, to the opportunities for training and careers in clinical investigation. A more sophisticated supply model, one that has both relevance and some basis in available data, would express supply as an explicit function of such variables as the numbers of medical students, house staff, and fellows; medical student interest in clinical investigation; and training positions in clinical investigation.

It is equally important to recognize how various disciplines change and open up whole new areas that cannot be predicted by these demand and supply functions. Examples include the impact of new diseases such as AIDS, the growing concern over alcohol and drug abuse in our society, and the growing geriatric population with all of their medical and social needs. Further, the demand for outcome assessment of health care from the standpoint of efficiency will also create a demand for more and more physician/scientists who have the tools to address these problems.

PROSPECTS FOR THE LONGER TERM: 1995 TO THE YEAR 2000

The preceding analysis of the labor markets for biomedical and behavioral scientists focused upon the period 1987-1995. As was discussed in the text, the policy options for this period are somewhat limited, given that the average time to complete the Ph.D. is in excess of eight years--that is, the "policy window" for the 1995 labor market is quite small.

What of the longer term--that is, to the turn of the century? Although the projections become more uncertain, the influence of policy as a corrective mechanism becomes stronger. The following discussion of a "status quo" future is based upon the assumption that the key variables--mainly enrollments, degree production, and employment growth--continue on the paths established during the late 1980s.

Biomedical Scientists

If recent trends in employment growth (4.1 percent annual rate) and attrition continue, job openings for biomedical scientists will exceed 8,000 per year by the year 2000. Replacement of scientists lost to attrition alone would require approximately 2,900 scientists. This is more than double the current level of Ph.D. production in the biomedical sciences, about 4,000 per year. Even if one assumes that growth falls to only 2 percent annually, job openings in the year 2000 would require 5,000 new Ph.D.s.

Behavioral Scientists

Unlike the market for biomedical scientists, the year 2000 labor market for behavioral scientists appears to be more in line with current levels of degree production. There exists the potential for imbalances in this market if even modest rates of employment growth are achieved during the 1990s; this is certainly a topic that needs to be monitored in the future.

Extending recent trends (2.0 percent annual growth) in nonclinical psychology employment growth through the year 2000 results in annual job openings of approximately 1,900 in that year. Current Ph.D. output of almost 1,400 would clearly be inadequate to meet this level of demand. However, it is the committee's opinion that current rates of employment growth will not be sustained; current levels of Ph.D. output should meet projected employment growth of 1 percent annually during the 1990s.

Employment growth in other behavioral sciences has been virtually nonexistent during the late 1980s.[14] Assuming a 1-percent growth rate results in approximately 1,000 job openings in the year 2000, this is in line with 1987 production of approximately 900 Ph.D.s.

Physician/Scientists

The current number of employee physician/scientists is estimated by the committee to be in the range of 15,000 to 20,000. Given historical trends in public and private biomedical R&D funding, it is probable that demand for physician/scientists will grow substantially in the 1990s.[15] However, it is difficult to project accurately the long-term labor market for physician/scientists because of the data deficiencies cited above. In addition, if demand for basic biomedical scientists continues to grow (as the committee projects), it is possible that physician/scientists will be asked to supply some of the basic science research effort in the biomedical field. The committee's recommendation to examine the issue of post-M.D. basic science training is consistent with this scenario (see Chapters 4 and 5).

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[14]Estimates from the Survey of Doctorate Recipients for total employment of other behavioral scientists was 12,478 in 1983 and 12,736 in 1987.

[15]Real funding for health-related R&D has been doubling approximately every 12 years since 1960. See Table B-7 in Volume II of this report.

CHAPTER 4

TOWARD MEASURING THE EFFECTIVENESS OF NRSA TRAINING PROGRAMS

OVERVIEW

NRSA personnel programs are designed to ensure the adequate supply and quality of biomedical and behavioral researchers. The principal mechanisms are fellowships, which influence individual career choices, and training grants, which also strengthen institutional training capabilities. However, the complexity of these NRSA programs, as well as methodological and data problems, makes it difficult to measure their effectiveness.

Recent studies of NRSA programs at NIH do suggest that participants outperform non-participants in terms of subsequent involvement in research during their careers. These differences held for a wide variety of performance measures, including grant applications, grants received, publication counts, and citation counts. It cannot be concluded from the studies, however, that the training programs were responsible for these differences. There have been no such evaluations of NRSA programs at ADAMHA or the HRSA.

Much of the information needed for more rigorous evaluations is available in existing data sets Other information could be gathered through surveys of former participants. More information is needed on the determinants of a research career and on the process used to select trainees. The biggest methodological problem is the lack of adequate control groups.

In the case of physician/scientists, program evaluations are more complex. Few M.D. trainees go on to careers of bench-level research, yet their clinical research is vital in applying new knowledge of molecular biology to patient care. Several reports have recommended changes in the program of study in training grant programs for physician/scientists.

Background

This chapter considers the two most advanced pools in the education pipeline: predoctoral and postdoctoral educational programs in biomedical and behavioral science.[1] The intent here is to examine how effective the National Research Service Award (NRSA) programs are in training individuals who move into successful research careers that meet national needs. A related concern is the question of how variations in effectiveness are related to program substance. With credible information about program effectiveness, plus more refined and thorough versions of the cost data presented in the Executive Summary, it will become possible to determine whether these programs demonstrate acceptable cost/effectiveness.

The committee was aware from the outset that it would be impossible to provide definitive information about the effectiveness of these training programs because of insufficient time and inadequate prior research and data bases. Our more realistic

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[1]We consider the words "training" and "education" to be synonymous, but the term "training program" in the context of this report often refers to specific educational efforts and participants supported in part by the National Institutes of Health (NIH) or Alcohol, Drug Abuse and Health Administration (ADAMHA) funds. In this context, training programs may be considered distinct from fellowship programs.

ambition was to derive a program of research and data improvement that, when implemented, could provide important steps toward definitive evaluations.

The Education Pipeline

Vital national interests require adequate supplies of highly qualified health-related scientists. As was stressed in the Executive Summary, our education pipeline--from elementary schools to universities and professional schools--is the key mechanism for assuring both the adequacy of the supply and its quality. Public policy must focus on effective and efficient ways to ensure that the highest quality and appropriate numbers of scientists are produced by the pipeline while at the same time containing costs.

However, the complexity of producing new entrants into science makes it difficult to affect the course of the process. In addition to being leaky, the U.S. educational system is decentralized, ill-coordinated, and only loosely coupled. In an ideal world the lower levels of an educational system would guide properly prepared young people toward the universities and colleges. These institutions would in turn provide basic scientific training to especially talented young people and encourage them to pursue scientific and professional training and apprenticeships in graduate and professional schools. In that perfect educational system, every young person who showed promise would advance along the pipeline promptly and in proportion to their promise.

In reality, however, local school boards run primary and secondary schools under loose state coordination, universities operate under a variety of jurisdictions, and science departments enjoy a remarkable degree of autonomy within universities. In this less-than-ideal world, therefore, the choice points that move one toward scientific and professional occupations are unclear, both to students and to educational institutions. This lack of clarity, together with the cumulative nature of the pipeline, makes it easier to get out than to stay in. A second result of this uncoordinated educational system is that policies directed at just one of the critical points cannot produce maximum effects, because the processes taking place at any one critical juncture only partially control the total production scheme. The only exception may consist of policies directed at the last stage--graduate and professional schools. Even though the flow is smallest at this point, the degree of leakage appears to be among the largest. Policies that stem this leakage could simultaneously affect improvements in the quality of training.

This discussion requires two caveats. First, even if new pipeline policies are implemented, their effects may take years to become discernible because of the length of the pipeline. Second, as in other areas of human behavior, public policy may be only a minor factor in shaping the flow of personnel into the work force of science; endogenous processes dominate the shaping of that flow. As a result, the effects of policy innovations may be slight and will be manifested only over long time periods. Their detection requires very sensitive measurement, and their analysis needs sophisticated research.

THE AIMS AND EFFECTS OF TRAINING AND FELLOWSHIP PROGRAMS

The overall goals of NRSA personnel programs are easier to state than to achieve. As a matter of policy, they are intended to ensure that the *supply* of biomedical and behavioral research personnel is sufficient to meet the demand, that their *quality* is high enough to meet the needs of a constantly improving level of biomedical research, and that the *pool of skills* is responsive to shifts in the demand for various kinds of specialized personnel.

To reach these goals, the policy uses a number of devices whose adoption is based on assumptions, explicit or implicit, concerning how occupational choices are made, how biomedical research skills are acquired, and what the market for biomedical research

personnel will be. It is useful to examine the first two sets of assumptions to see how closely they match the actual programs pursued and to consider the alternatives to those assumptions that were not adopted. (Labor market issues were considered earlier in this report.)

Occupational Choice

The most direct goal of NRSA programs is to influence the occupational choices of potential research personnel. The implicit model is that critical choices at each point in the career path are influenced by the balance between anticipated benefits and costs of alternative paths. NRSA programs are designed to influence the balances by lowering costs of particular choices through stipends.

The effectiveness of this strategy depends not only on when the stipend is offered, but also on the array of alternative choices offered by the environment. In many engineering fields, for example, graduate stipends must compete against immediate employment as a B.S. engineer. Similar competitive circumstances face fellowship programs designed to recruit M.D.s into research.

Training

Another purpose of NRSA programs is to provide students with training opportunities that may not otherwise be available to them. (In this context, training is meant to cover both formal course work and apprentice-like participation in research.) This purpose can be achieved in two ways: either by enhancing the ability of academic departments to provide training, or by improving the range and quality of training choices available to students.

Training grants may be best at enhancing institutional training capacities, for instance by expanding the number of traineeships, providing a departmental focus, or enhancing opportunities for cross-disciplinary training and research. However, it is an open question whether trainees receive different educational experiences than other graduate students in the same departments. Stipends may release students from the necessity to support themselves by unrelated employment, but traineeships may also compete with employment that is directly related to training, particularly research assistantships in which graduate students directly participate in faculty research as apprentices. It is unclear whether the quality of training is affected by being employed as a trainee rather than as a research assistant.

Fellowships awarded to individuals provide fewer advantages to departments, but they too enhance training opportunities for individuals and may also enhance the research of the faculty sponsors.

Training Efficiency

All other things being equal, the shorter the training period, the more research personnel can be produced. Traineeships and fellowships are believed to shorten the training period by making it less necessary for their incumbents to engage in income-generating activities that are not training opportunities: the more time devoted to training, the quicker it is attained.

Several caveats must be taken into account in assessing this argument. First, the greater efficiency of the entire biomedical and behavioral research personnel "industry" can only be attained if there are qualified and promising candidates for training who cannot be accommodated by the industry's capacity. Second, stipends are fungible--they can substitute for job earnings unrelated to training, but they can also increase the

consumption of goods and services or even prolong one's stay in a training position. The fungibility of stipends also allows departments to use stipends to substitute for other funds, thereby increasing the resources available for other purposes or, more likely, increasing the number of graduate students. The connection between traineeship or fellowship strategies and increased efficiency is not necessarily causal except where expansion is required as a condition for awarding a grant.

Honor

Because fellowships and traineeships are awarded mainly in competition, they honor those who win the awards and hold the resulting positions. Honor may affect subsequent performance by increasing self-esteem, self-confidence, and the expectations of others. This effect may be reduced if traineeships are doled out in the same manner as other support, while fellowships awarded by national competitions may carry additional honor.

Merit-Tested Selection

Traineeships and fellowships presumably go to the most promising among the pool of eligible candidates. Ironically, those most likely to be selected are also those most likely to become biomedical researchers without the traineeship or fellowship in question. As a result it is difficult to estimate the net effects of biomedical and behavioral research personnel programs. If every promising candidate receives some support, there will be no available controls--no persons of equal merit who were not chosen. (Statutorily ineligible persons, such as foreign nationals, differ from those chosen in other important respects.) Programs that use merit-tested selection can only be evaluated for their net effects by drastically altering the selection process in what may be regarded as undesirable ways. It might be tempting, for example, to randomly deny fellowships and traineeships to selected persons in order to form controls, but such a strategy would surely produce both unsatisfactory controls and strong opposition.

Marginal Effects

A final policy concern is the marginal effects of the programs: how much would be gained from expanding the program? Marginal effects are especially of interest for programs that are not likely to be terminated, have not reached saturation coverage, and in which policy concerns center around whether the program should be expanded (or contracted). Biomedical and behavioral research training programs are unlikely candidates for termination, but their level of support does sometimes come under scrutiny. The issue of coverage saturation is not settled: there may or may not be additional traineeship or fellowship candidates who are qualified for support. The import of this discussion is that, whatever estimates are made of the effects of the biomedical research personnel programs, attention should be given in the first place to its marginal effects in preference to estimates of main effects.

THE EVALUATION OF TRAINING AND FELLOWSHIP PROGRAMS

Recent evaluation activities related to the NRSA programs have addressed the above questions and serve to identify areas of highest priority for future research. (A detailed discussion of these activities is found in the commissioned paper by Georgine Pion, found in Volume III of this report.) Such evaluations may serve two different purposes: definitive or descriptive. That is, an evaluation may aim at a definitive statement describing the effects of a program (i.e., a statement of how the world would be different if the program did not exist and evidence of the truth of that statement that is sufficiently rigorous to be acceptable to the scientific community). This requires well-designed research: the programs may have small effects, delayed effects, effects that differ for different subpopulations and under different conditions, and control groups are difficult

to find. There has been no evaluation of an NRSA program to date that would meet reasonable scientific standards for a demonstration of causality.

Recent evaluation activities have instead sought the much more modest goal of providing some facts about certain aspects of the program. Most were outcome studies that examined selected aspects of the subsequent careers of recipients and compared them to persons who did not receive NRSA support. These outcome studies are reviewed in the next section, as are the gaps in knowledge about NRSA that appear important to fill. These evaluations do not include any causal inference, but they can still support judgments about the attributes of appropriate policy. For example, if practically all graduates of a particular training program have outstanding research careers, it may be judged good policy to continue the program, even if the program had no causal effect on its recipients' careers. If on the other hand very few graduates of a program ever enter research, it may be judged that the program is not worthwhile, even if the program does have a causal effect on those who do succeed. Most evaluations fall between these two extremes.

Outcomes

What happens to persons who receive research training support from the NRSA program? Recent attempts to answer this question focused on indicators of whether the graduates are engaged in health-related research and measures of scientific productivity (e.g., grant application data, publications, citations).[2] These studies typically construct a "comparison group" of persons who did not undergo NRSA training, with which to compare the performance of those who were in the NRSA program. In practice, however, comparison groups have been poorly matched; perfect matching is likely to be impossible. This methodological problem weakens the conclusions that might be drawn about the effect of NRSA training programs on performance differences.

The consistent finding of almost all of the evaluation studies is that NRSA awardees outperform comparison group members in terms of research involvement during their careers. The magnitude of the difference between participants and the comparison group depends in part on the composition of the comparison group. For example, Coggeshall and Brown used two groups for comparison with those who received pre-Ph.D. support under NRSA.[3] The first group consisted of age-matched Ph.D.s who received their degrees from departments that had received an NIH training grant but who had not received an NIH stipend themselves. The second comparison group consisted of Ph.D.s who had received their degrees from other departments and who had not received NIH support themselves. The study found that the performance of participants in NIH-sponsored predoctoral training modestly exceeds the performance of nonparticipants from the same departments and greatly exceeds the performance of the second comparison group. This was true for a wide variety of performance measures, including postdoctoral research support, subsequent involvement in NIH research, publication counts, and citation counts. Given that the first comparison group should have received exactly the same graduate education as the NIH trainees, the differences suggest that at least some training grant directors are effectively selecting their better Ph.D. students for the NIH award.

A second study found that NIH post-Ph.D. awardees also go on to have more research-intensive careers than do members of two comparison groups: (1) biomedical science Ph.D.s who indicated on a survey that they planned to take a postdoctoral

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[2]For an extensive discussion of the concept of productivity, see the paper by Helen H. Gee in Volume III of this report.

[3]Porter Coggeshall and Prudence Brown, *The Career Achievements of NIH Predoctoral Trainees and Fellows*, Washington, D.C.: National Academy Press, 1984.

appointment but did not receive NIH support and (2) biomedical science Ph.D.s without postdoctoral plans.[4] Again, the differences appear on many performance measures (grant applications, publication counts, citation rates) and were much greater for the second comparison group than for the first.

Garrison and Brown also studied the post-training performance of NIH M.D. postdoctoral awardees. Here, because research is unlikely to be the career goal of a physician, there are substantial problems in developing an informative comparison group. Comparison data were collected for (1) all M.D.s and (2) a subset of M.D.s who said, a few years after their degree, that their primary activity was either research or teaching. Not surprisingly, the proportion of NIH M.D. postdoctoral awardees who were engaged in research or teaching exceeded that of the typical physician. The subsequent research involvement of M.D.s who had received an NIH fellowship also greatly exceeded the comparison group of self-identified researchers and teachers. However, M.D.s who had received NIH postdoctoral support under a training grant were *less* likely to be involved in research than the comparison group of self-identified researchers and teachers. This unexpected result merits replication; if the finding is repeated, it merits further investigation as part of a program of research into outcomes of NRSA training programs.

A more interesting question is how these outcomes are related to program characteristics. The best information would let one estimate how outcomes for NRSA trainees would change if small amounts of funds were shifted among programs (e.g., from institutional training grants to fellowships awarded to individuals). Training grant programs and individual fellowship applications are assigned priority scores to describe the scientific merit of each application; and (in most NIH programs) funding decisions for each award are made in priority score order. The "payline" is the point at which funds run out. If the outcome for persons who receive training under an application that is close to the payline for each type of grant were known, then one could estimate how the outcomes for NRSA trainees would change if small amounts of funds were shifted among programs. However, none of the studies addressed the relationship between outcome and the priority score given to the fellowship or training grant application.

There is some information about the average outcome for recipients of various components of the NRSA awards. It is important to compare only programs with a reasonable chance of having comparable results. For example, one must expect that post-Ph.D. programs will produce a higher return in researchers per trainee than predoctoral programs because of the greater commitment to research demonstrated by those persons who have successfully completed the Ph.D. and applied for a postdoctoral appointment. Also, because the current M.D. curriculum provides little research training, one must expect a greater return in researchers per trainee from post-Ph.D. programs than from post-M.D. programs. To do better it would be necessary for selected M.D.s to have had enough research experience to be similarly committed to a research career. (See page 58, "A Special Note on the Training of Physician/Scientists.")

The most comparable programs are training grant and fellowship programs aimed at persons with the same previous research training. The few evaluation studies that addressed this issue found that fellows outperformed trainees on most measures of subsequent research involvement. The differences were less pronounced for Ph.D.s than for M.D.s, however: 62 percent of post-Ph.D. fellows applied for an NIH or ADAMHA

[4]Howard Garrison and Prudence Brown, *The Career Achievements of NIH Postdoctoral Trainees and Fellows*, Washington, D.C.: National Academy Press, 1986.

research grant, compared to 52 percent of post-Ph.D. trainees; for M.D.s, the corresponding figures are 43 percent for fellows and 17 percent for trainees.[5]

It would be desirable to know how outcomes are related to other aspects of the NRSA program. The section on the training requirements for physician/scientists (below) notes the empirical evidence supporting the hypothesis that the length of time spent in postdoctoral research training is a strong predictor of the subsequent research involvement of M.D.s. What is not known, however, is the amount of time M.D. recipients of NRSA awards spend in research training supported by non-NRSA mechanisms, such as privately supported fellowships.

There also have been no adequate studies of the outcomes of two of the most promising (and expensive) ways of training physician/researchers: the Medical Scientist Training Program and the Physician/Scientist Award Program. Because they both provide longer periods of NIH-supported research training, they may also yield substantially higher returns to research than the more traditional fellowship and training programs, but the facts currently are unknown.

Most evaluation activities have focused on NRSA programs administered by NIH. The few studies that included ADAMHA awardees tended to use fewer outcome measures. There have been no evaluations of the NRSA programs sponsored by the Health Research Service Administration. Similarly, there have been no evaluations of the effect of training grants on the training capacity or training efficiency of recipient institutions.

Data Needs for Program Evaluation

Program statistics on the number and characteristics of persons receiving each type of award are the most basic information about the training received by NRSA recipients.[6] To provide this information, NIH sponsored the creation of the Trainee Fellow File, which provides information on all NRSA students, and the Consolidated Grant Application File, which contains information on programs for advanced research training and on institutional awards. One deficiency in these data bases is the difficulty involved in constructing definitions of attributes, such as field of study, that will provide consistent time series. A second problem is the lack of information about program outcomes. A third deficiency is the lack of a set of adequate measures for career outcomes, including scientific productivity. The proposals for a framework for evaluating program effectiveness and for an evaluation data matrix (discussed below) would remove many of the difficulties involved in the use of these data.

The evaluation matrix proposed in the appendix would deal with the ease of use of currently available statistics. However, there are three areas where all currently available statistics are inadequate: research participation by physicians,[7] non-NRSA sources of support for research training, and program evaluations by former trainees. In many medical schools the faculty roster conducted by the Association of American Medical Colleges (AAMC) is not answered by the individual faculty member; as a result, the information in the survey is frequently out of date or otherwise inaccurate. The only firm information available on the amount of time that physicians spend on research comes from

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[5]Garrison and Brown, *op. cit.*, Tables 4.2 and 8.2A.

[6]See the appendix for a further description of existing and proposed data sets discussed in this chapter.

[7]Research participation by Ph.D.s is covered in the SDR.

a one-time survey of the faculty of departments of internal medicine.[8] Information is lacking on other specialties.

Information about sources of support would be obtained most accurately from a survey of the training sponsors, although it could also be collected on an individual basis. This information would give a more accurate picture of the total training received by NRSA recipients and would greatly facilitate the design of more effective evaluation studies.

Some outcome measures are available from data sets such as the SDR and the Institute of Scientific Information's Science Citation Index. Other basic measures are available only from former trainees themselves (and, where appropriate, from credible comparison groups). Former trainees' assessments of the impact of NRSA training on their subsequent careers is just one basic set of information that could be of substantial value in future versions of this report. Other valuable items would include sense of satisfaction with one's career and sense of contribution to the field. Because the SDR is based on a small sample, it is usually inappropriate as the source of inferences about small populations such as NRSA trainees in a given field of science. In this case, occasional surveys of former trainees and appropriate control groups are altogether warranted.

Very little is known about the process used to select trainees for institutional grants. No records are kept of unfunded applicants or of persons who are offered a traineeship but turn it down. The lack of such basic information about the demand for training makes it difficult to assess important parameters of the program, such as the level of stipends and the effects of the payback provision.

Finally, and perhaps most importantly, there is a great need for basic research on the determinants of a research career. NRSA programs attempt to intervene in a complex decision process that is poorly understood. Little is known about how the characteristics of a training program affect the research abilities of persons who participate in that training.[9] Although the recent evaluation studies suggest that NRSA training is correlated with success as a researcher, the correlations are very small: the total effect of NRSA training and other indicators of preexisting quality explained only 6-14 percent of the variance in outcome measures. Better understanding of the factors that influence career decisions and research ability is the key to designing more effective and efficient training programs.

A FRAMEWORK FOR PROGRAM EVALUATION

There are two major limitations in conducting an adequate evaluation of NRSA programs: (1) inadequate control groups with which to compare the awardees and (2) inadequate measures of many of the outcomes that need to be assessed. As discussed above, the problem of control groups is related to the process by which trainees are selected: those selected might have more successful careers (by whatever measure) than those not selected, independent of the advantages provided by the training program. An ideal experimental design would consist of choosing trainees randomly, independent of their characteristics, so that differences in career outcomes could be attributed to the effect of the training program. This ideal methodological approach is unreasonable in practice. A reasonable and practical alternative to random selection would be careful study of the process that

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[8]G. S. Levey, et al., "Postdoctoral Research Training of Full-time Faculty in Academic Departments of Medicine," *Annals of Internal Medicine*, vol. 109, no. 5 (September 1988), pp. 414-418; their findings are discussed in Chapter 5 of this report.

[9]Coggeshall and Brown, *op. cit.*; Garrison and Brown, *op. cit.*

determines selection as an NRSA trainee. This approach would also provide insights that can be used to improve the selection process and, to the extent that the process is modeled adequately, it would be possible to introduce statistical controls into the analysis of the effects of being a trainee on career outcomes. Consequently, the committee's first recommendation in designing future evaluation studies is to include detailed information on the process by which trainees are selected from all applicants. The next step is to model the effects of the training program on career outcomes, including productivity measures.

The commissioned paper by Helen H. Gee (see Volume III of this report) establishes guidelines that should be used in planning productivity assessments, including a number of general points about the use of productivity measures for NRSA programs:

- Define program goals specifically enough to provide guidance in constructing measures of their success. For example, "contribute to the research enterprise" does not narrow down the many ways this can be accomplished--through publications, patents, administration, and teaching.

- Recognize multiple pathways (activities and career paths) that can lead to those goals by designing evaluation studies that assess the variety of potential outcomes.

- Exclude those scientists whose career paths and research productivity cannot be assessed adequately with available methods and data. For example, if methods for assessing the productivity of nonacademic scientists are not practical, those scientists should be excluded from comparisons of other groups.

- Identify the uses to which the results of the assessment are to be put and let them guide the design of evaluation studies. Evaluations designed to assist program managers, for example, will not necessarily provide the information required by those making policy decisions.

Recent evaluation studies have tended to focus exclusively on the single measure of publications and the single characteristic of whether or not the trainee sought funding from NIH. The committee recommends that future studies consider a broader spectrum of outcome measures, including the following:

- receipt of a Ph.D. (for predoctoral trainees);
- time required to complete the Ph.D. (for predoctoral trainees);
- years of postdoctoral training;
- type of employer;
- type of work activity;
- pursuit and receipt of NIH and ADAMHA funding;
- publications and citations; and
- area of research.

For the evaluations to be most effective, these measures (many of which have been used in other studies) should be followed over an extended period of the career rather than be measured only at a single point in time. Longitudinal studies should be used that track changes in employers, work activity, grant activity, publications, citations, and area of research over at least the first decade of the career. Statistical comparisons of the career activities of trainees and the control group will provide a much better insight into the effectiveness of NRSA training programs.

In summary, it is possible to design and carry out research that will produce unbiased estimates of marginal program effects by carefully expanding the program to

include additional trainees and fellows. Persons selected under this controlled expansion need to be followed over a period of time. Furthermore, the heterogeneity of the programs' aims and mechanisms also create difficulties because there are many kinds of intended effects and additional side effects--some desirable, some simply benign, and others possibly subversive of the main aims of the programs. Thus, the committee recommends that two evaluations of program effects be undertaken:

1. A comprehensive assessment of the effects on institutions, departments, and individual trainees and fellows and

2. A less comprehensive evaluation of the effects of program participation on individual awardees.

A SPECIAL NOTE ON THE TRAINING OF PHYSICIAN/SCIENTISTS

Program evaluation for clinical investigators is further complicated by the complexities of training and tracking the academic physician/scientist. M.D. faculty are supported in their research training not only through NRSA fellowships and institutional training grants, but also by a variety of foundations and volunteer health agencies. Thus, receipt of NIH support for post-M.D. training and receipt of post-M.D. training are not synonymous.

Evaluation is further complicated when application for and receipt of NIH research grants (generically called R01) by former trainees are used as program outcome variables. The subsequent careers of M.D. awardees may involve (1) no research, (2) bench-type research, or (3) academic "hands-on" patient research. It is predominantly those in the second category--a comparatively low number--who are likely to apply for and obtain NIH R01 research support. Yet there is evidence that far more M.D. faculty in the third category--perhaps as many as 50-60 percent of the total NRSA M.D. trainees--are doing productive clinical investigation but not at the bench level that is generally required for NIH R01 funding.

There is a vital need for well trained clinical investigators who can take the enormous explosion of knowledge in molecular biology and apply it to the care of patients. Over the last decade, however, it has been increasingly difficult for clinical investigators doing hands-on patient research to obtain funding through NIH. These individuals may account for a very large proportion of the "unsuccessful" trainees from the NRSA institutional grants. If so, they must be identified and quantified for adequate program evaluation. The same holds true for the cadre of clinical investigators who will have to be trained in the methodologies of epidemiology, biostatistics, health services research, economics, and outcome assessment in the near future.

James Wyngaarden, a former director of NIH, has emphasized that research training and career development programs have a priority for NIH "virtually equal to the support of research project grants."[10] He also acknowledges, however, that NIH-sponsored training programs have variable success rates, with the least certain being the traditional training programs for physician/scientists. Far too few of these M.D. trainees apply for and receive NIH research grants, according to Wyngaarden, and some training programs merely serve as support vehicles for subspecialty clinical training. He calls for a comprehensive, critical review of NIH research training programs, specifically whether examining current training programs for physician/scientists should be modified.

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[10] J. B. Wyngaarden (memorandum to BID Directors and OD Staff), "Review of NIH's Biomedical Research Training Program,' April 19, 1989.

Wyngaarden's position is echoed by Lloyd H. Smith (see Volume III of this report). Smith's position is that the serious physician/scientist must receive in-depth training in a scientific discipline relevant to medicine and that rigorous scientific training can rarely be achieved in a specialty division of a clinical department. Smith argues that the training of physician/scientists should be comparable to Ph.D. programs in rigor and scope and that the physician should not be burdened with clinical responsibilities during the research training period. Smith believes that at least three years of rigorous training in modern biological science is usually necessary for most individuals to achieve independence as an investigator.

Smith's paper buttresses remarks made by Joseph Goldstein in his 1986 address to the American Society for Clinical Investigation. Paraphrasing from that address, intelligence, curiosity, and drive are necessary but not sufficient for the productive physician/scientist; there must also be technical skill and the ability to reduce a complicated clinical phenomenon to a manageable biochemical problem.[11] Given the complexities of modern biomedical research, a clinical investigator must have a sophisticated understanding of the fundamental sciences, a mentor in the sciences to direct development, the opportunity to learn techniques, and uninterrupted time in the laboratory to conduct the research.

Those committee members who have experience in the training of physician/scientists endorse the suggestions made by Smith and Goldstein and suggest that the following changes be made in the postdoctoral institutional training programs for physician/scientists:

- a true consortium between the clinical and preclinical departments of the institution, with shared responsibility for the design and administration of the program;
- selection of trainees based on evidence of some previous experience in research and overall promise;
- formal course work in the physical and biochemical sciences sufficient to give graduates a theoretical background comparable to those with graduate degrees in the biological sciences;
- not less than three years of research training, primarily in direct research experience under the supervision of a mentor; and
- modules of instruction, specifically tailored to the needs of the physician trainee, in such areas as basic laboratory techniques, chromatography, radioimmunoassay, protein purification, advanced instrumental techniques, fundamental principles of enzymology and molecular biology, subcellular fractionation techniques, computer technology, evaluation of experimental data, epidemiology, and statistics and data base management, as well as grant and manuscript writing.

A 1986 survey of full-time faculty in departments of medicine made similar recommendations regarding postdoctoral research training.[12] The survey identified several

[11]J. L. Goldstein, "On the Origin and Prevention of PAIDS (Paralyzed Academic Investigator's Disease Syndrome)," *Journal of Clinical Investigation*, vol. 78, 1986, pp. 848-854.

[12]G. S. Levey, et al., *op. cit.*

features of training experiences that were associated with the faculty member currently being an active researcher, including the following:

1. Most postdoctoral training occurred in medical schools and the primary source of funding was NIH.

2. For faculty members with an M.D. degree, the length of training was a significant predictor for subsequently being an active researcher and principal investigator for a peer-reviewed research grant.

3. The average length of time between the end of postdoctoral research training and obtaining the first peer-reviewed research grant was 24 months, regardless of length of training, source of training support, training site, or type of academic degree (M.D., M.D./Ph.D., or Ph.D.).

4. Respondents advocated incorporating formal course work, particularly in the basic sciences and statistics, within the structure of the postgraduate training programs, with less time allocated to patient care.

5. Contributing factors to being a successful researcher in academic medicine include the following: two or more years of postdoctoral research training, including formal course work in the fundamental sciences pertinent to biomedical research; two to three years of full research funding from an academic institution until the first extramural grant is obtained; and the investigator's commitment of at least 33 percent of time to research activities.

The former trainees, upon reflection, favored changing the curriculum to include more formal course work and training in fundamentals, particularly mathematics/computer science, statistics, research techniques, grant administration, and medical writing. Of equal interest, the vast majority (65 percent) wanted less time devoted to clinical medicine during the training program. The committee as a whole finds merit in these suggestions and recommends that NIH establish a committee, conference, or study to consider whether changes should be made in the program of study in postgraduate institutional training grants for physician/scientists.

Deficiencies in the evaluation of these training programs are described in detail in the commissioned paper by Georgine Pion (see Volume III of this report). There are inherent difficulties in retrospective survey designs, and evaluation must focus on the career development of those who trained as many as 10-15 years ago to determine long-range effects of these training programs. The evaluation must also define what constitutes "success." For example, although this committee may conclude that institutional training grants need to be revised, it also recognizes that even in their current form, these programs have made a positive contribution. Graduates of the institutional training grants have populated all the clinical departments in our medical schools and, even during their short training periods, they have done valuable research work in the laboratories of established investigators.

Chapter 5

RECOMMENDATIONS

LEVELS OF NRSA SUPPORT

Basic Biomedical Sciences

The key findings are as follows:

1. The number of biomedical Ph.D. awards and labor demand (job openings) have been in approximate balance since the early 1980s; the ratio of job openings to new Ph.D.s is expected to increase through the year 2000.

2. Industry is and will continue to be the dynamic sector for employment growth with the majority of new vacancies occurring in this sector.

3. The growth rate for research and development (R&D) employment will exceed that for total employment for the foreseeable future. This is due in large part to the relative growth of the industrial sector, whose biomedical Ph.D.s are heavily involved in R&D.

4. Women are a growing proportion of the biomedical labor force. Given that women are less likely than men to be involved in full-time science, their increasing participation may lead to higher outmigration and less effective labor supply.

Based on these considerations, the committee recommends sl.. ting the NRSA program towards Ph.D. production. This could be done in three ways:

1. *Increase the level of predoctoral support.* There is evidence that enrollments in the biomedical sciences are very responsive to increasing student support.[1] The committee recommends that the level of predoctoral support be increased to 5,200 from its current level of 3,681 full-time equivalent positions.

2. *Improve the graduation rate of Ph.D. candidates.* This would have a substantial impact on labor supply.

3. *Decrease the time needed to complete the doctorate.*[2] There is evidence to suggest that student support during the thesis considerably shortens this time.

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[1]It has been estimated that first-year biomedical Ph.D. enrollment increases 1.35 percent for each 1-percent increase in the number of students who have support. See Joe G. Baker, "The Ph.D. Supply Crisis: A Look at the Biomedical Sciences," paper g' at the Western Economics Association Meetings, June 21, 1989, Lake Tahoe, Nevada.

[2]The increasing time to the doctorate has hampered Ph.D. labor supply in two ways. First, it has retarded the labor supply response to such stimuli as increasing wages and student support. Second, it has increased the investment costs of graduate education, resulting in lower enrollment. See Joe G. Baker, *op. cit.*

The committee suggests that NIH examine the potential utility of a program tailored specifically for student support during the thesis-writing stage.

Needed levels of postdoctoral training support will depend upon (1) the requirements of industry for this level of training and (2) decisions as to whether the public sector should support postdoctorals for industry. If the demand/supply balance that existed during the early 1980s is to be maintained, total postdoctoral support must increase from its current level of approximately 8,200 to around 11,500. The current level of NRSA postdoctoral support, around 3,700, should be increased gradually as the number of Ph.D. degrees increases.

Serious questions have been raised about whether postdoctoral training represents a useful added educational experience designed to enhance productivity, or whether instead it is merely a holding tank for those doctoral scientists who are unable to land a suitable job.[3] Evidence on this issue is sufficiently flawed by methodological problems as to leave it an open question about which convincing research is needed. A suggestive fact revealed in a survey carried out for the committee is that industrial employers of biomedical scientists prefer those with postdoctoral training credentials. The committee believes strongly that postdoctoral training programs in biomedical fields should be retained and even expanded moderately, but recommends thorough program evaluations at both predoctoral and postdoctoral levels.

Behavioral Sciences

The following are the key findings:

1. Most of the employment of nonclinical psychologists and other behavioral scientists occurs in colleges and universities. Given the assumption of modest enrollment growth in behavioral sciences, growth in demand for academic behavioral scientists will also be modest.

2. The labor market for nonclinical psychologists and other behavioral scientists has been fairly stable through the 1980s.

3. There is potential for behavioral science demand growth to exceed new Ph.D. supply in the post-1995 period. This is especially true if degree awards continue to fall.

4. Behaviorally-based health problems (AIDS, drug and alcohol addiction, tobacco, cancer, etc.) are increasing in importance. For this reason, it is important to the nation's health that NIH/ADAMHA continue to support behavioral science research and research training.

Given these considerations, the committee recommends that predoctoral and postdoctoral support be kept at their current levels of approximately 500 and 420 full-time equivalent positions, respectively. However, the committee also recommends moving support away from clinical psychology toward nonclinical psychology and other behavioral sciences. The level of support for scholars in the area of health services research should be increased (see below).

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[3] P. E. Coggeshall, et al., "Changing Postdoctoral Career Patterns for Biomedical Scientists," *Science*, vol. 202 (November 3, 1978), pp. 487-493.

Clinical Sciences

1. The committee recommends that the current number of trainees and fellows for M.D. investigator training remain essentially as it has been (approximately 2,150). Although the demand for M.D. investigators likely will increase, the committee feels that proposed studies of the training mechanisms and training outcomes for the various programs should be carried out before significant changes are made. It is hoped that these steps will be taken soon.

2. The level of support for M.D. research training in the area of health services research should be moderately increased.

DATA IMPROVEMENTS, NEEDED RESEARCH, PROGRAM EVALUATION, AND ADMINISTRATIVE INFRASTRUCTURE

The committee has identified new activities in each of these areas that would improve understanding of scientific personnel issues and improve the quality of future versions of this report. The committee recommends that NIH/ADAMHA put in place the necessary interim staff and begin immediately the programs of data improvement, research, and evaluation proposed below.

Small-Scale Data Improvements (not in priority order)

1. *Improve employment specialty information in the Survey of Doctorate Recipients (SDR)*: An important component of the labor market is occupational mobility; this mechanism is a source of both labor supply and demand for new scientists in the biomedical and behavioral fields. It is the opinion of the committee that the list of occupations included for self-identification in the existing SDR survey form is too restrictive and makes it difficult for a Ph.D. who has moved out of science to respond to the survey. As a consequence, it is likely that outmobility from science is understated. This issue needs to be examined with a goal of improving the employment specialty information on the SDR.

2. *Add a salary item in the Doctorate Records File (DRF)*: The DRF is a census of all Ph.D. recipients from U.S. universities, collected continuously as degrees are granted. These data provide information on the new doctorate recipient's plans after graduation (approximately 60 percent of Ph.D.s have definite postdoctoral plans at the time the DRF survey form is completed). The inclusion of an item on expected salary for those with definite plans would give a mechanism for continuous monitoring of the relative tightness of the Ph.D. labor market by detailed fields, quality of degree-granting institution, sector of employment (academic, industry, federal lab, etc.), and other variables. These salary data would provide a baseline for analysis and modeling of the Ph.D. labor market at minimal cost.

3. *Improve response rate and evaluate nonresponse bias of the SDR*[4]: The SDR is the main data set used in the analysis of the Ph.D. labor market. These data are based upon a biennial survey of approximately 10 percent of the U.S. doctorate work force. The survey is plagued with relatively low response

[4]This recommendation is consistent with that contained in a recent evaluation of the NSF data system. See C. F. Citro and G. Kolton (eds.), *Surveying the Nation's Scientists and Engineers: A Data System for the 1990s*, Washington, D.C.: National Academy Press, 1989.

rates and the attendant possibility of serious nonresponse bias. Two steps need to be taken:

a. Analyze the extent of nonresponse bias. The last such study of these data was conducted in 1979. The committee endorses the recent effort by NSF to update this study, now under way.

b. Assemble an ad hoc committee of experts in survey research methods to design approaches that will improve the SDR's response rate.

4. *Include a postdoctoral identifier in the SDR*: The evaluation of postdoctoral study as a research training method is critical if future policy is to be suggested. The current structure of the SDR makes it difficult to determine whether a scientist has participated in postdoctoral study; the inclusion of a question regarding this activity would allow for a more thorough evaluation of postdoctoral support.

Larger-Scale Data Improvements (in priority order)

1. *Establish a program evaluation data matrix*: To assess the numerical adequacy of the nation's biomedical and behavioral research personnel and to make judgments about the quality of their training, we need both quantitative and qualitative information. The data matrix discussed in the appendix could provide such information. The committee recommends that the training data be organized and analyzed as suggested by that data matrix framework.[5]

2. *Reconcile SDR postdoctorate estimates and those of the Survey of Graduate Science and Engineering Students and Postdoctorates (GSESP)*: There are two sources of information on the level of postdoctoral utilization: the NSF/NIH SDR and the NSF/NIH GSESP. These surveys are inconsistent. The ambiguity of these data made it difficult for the committee to determine the historical trends in postdoctoral appointments; this, in turn, made recommendations about future levels difficult. This issue needs to be resolved to improve the analysis and evaluation of the NIH/ADAMHA postdoctoral effort. The effort may require a separate one-time survey.

3. *Improve research identification on the NIH/Association of American Medical Colleges (AAMC) Faculty Roster*: Historically, the main source for data on physician/scientists has been the AAMC Faculty Roster. Subsequent studies have shown that Faculty Roster data are inadequate to define precisely the actual research activities of faculty and the quality of their research effort. A better identification of researchers and their activities must be achieved, in terms of both the AAMC questionnaires to deans of schools of medicine (Faculty Roster) and the NIH tracking of its institutional National Research Service Award (NRSA) training grant awards. Simple identification of self-designated researchers without any effort to quantify the amount and quality of research is meaningless.

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[5]This recommendation is consistent with that of the Task Forces for the Review of NIH Biomedical Research Training Programs. See the NIH "Review of the National Institutes of Health Biomedical Research Training Programs," mimeographed, October 1989, p. xvii.

Needed Research (both sets of equal priority)

1. *Studies of recruitment and retention throughout the academic pipeline*: We urgently need more comprehensive knowledge on recruitment to and losses from the pipeline into biomedical and behavioral science, especially about women and minorities at all stages of the pipeline. The committee recommends a program of research, beginning with one or more commissioned papers that summarize and synthesize the literature on the subject with emphasis on the evaluation of intervention programs at critical nodes in the pipeline. Given the anticipated labor shortages in biomedical sciences, improvement of graduation rates and participation in full-time science after graduation are important issues.

2. *Survey studies of former trainees with control groups*: The program evaluations recommended below should contain several novel components relative to the prior evaluations described in the commissioned paper by Georgine Pion (see Volume III). One of these should be a series of surveys of former trainees and of carefully designed control groups. The surveys should concern career outcomes that are not reflected adequately in available secondary data, including job satisfaction and future pl s, as well as the success of those in academe as undergraduate and graduate teachers. They should center on retrospective evaluations of their pre- and postdoctoral studies and, for former trainees and fellows, on the value of the programs. Finally, they should tap aspects of the research career that are not available from other sources, such as patterns of research collaboration (locally and at a distance) and sources of research funds other than NIH/ADAMHA.

   These studies can feed into the set recommended above by defining study populations as graduate school entrant cohorts--not just doctorate recipients--who received NRSA support or who had the characteristics of a control group member. If done properly such studies could represent a major contribution, not only to needed program evaluations, but also to our understanding of the determinants and career consequences of attrition from graduate school.

Recommended Program Evaluations

The committee recommends two new, large-scale program evaluations that differ from prior efforts by including surveys of former trainees and fellows (see above) and field research that takes investigators onto the campuses at which the selected programs are located. We recommend the careful selection of individual programs within the two training categories for initial evaluation. Program directors, department chairs, trainees, and other students should be interviewed. Curricula should be evaluated and aggregate survey results discussed We recommend that the first two programs to be evaluated in this fashion be the Minority Access to Research Careers (MARC) and the Medical Scientist Training Program (MSTP). We recommend that the sequence of steps leading to these evaluations parallel those recommended for the two programs of research.

Interdisciplinary Programs

The committee urges NIH/ADAMHA to continue to evolve its predoctoral and postdoctoral programs to meet changing national priorities, and we support the need for some of these programs to be interdisciplinary in nature. But it is imperative that those trained in interdisciplinary, cross-disciplinary, or multidisciplinary programs be thoroughly trained in basic disciplines and capable of rigorous work of the highest scientific quality. Recently developed programs (such as biotechnology training) can accomplish these

objectives, provided that peer evaluations are sustained at high levels and are based on clearly articulated and applied criteria. This recommendation is based on the committee's firm belief that the solutions to complex health problems, such as the AIDS epidemic, cannot be specified or narrowly targeted. Breakthroughs may come from studies in many basic fields and are likely to be found at the conjunctions of fields. But they will be found only by researchers whose understanding of those fields is deep and who have the flexibility of mind and breadth of training that allow such discoveries to be made.

Needed Organization with Which to Implement These Recommendations

We recommend that a new committee be activated no later than January 1992 in order to allow two years for the preparation of the 1993 report. If the preceding recommendations are initiated promptly, that report will require two years of effort and should represent a major contribution to our knowledge of scientific personnel. In order that the studies be undertaken and coordinated, there will have to be one or more persons responsible for their administration and possibly research involvement.

Special Consideration: The Program of Study for Physician/Scientist Research Training

Those committee members with experience in the training of physician/scientists believe that the program of study for physician/scientists, with emphasis on the NRSA institutional training grant mechanisms, must be radically changed to meet the health needs of the nation.

Lloyd H. Smith notes that the science taught in specialty divisions of the clinical departments tends to be goal-oriented and superficial; although some physician/scientists have thrived in the environment and have had productive careers, most have been poorly prepared for sustained scholarship.[6] Smith believes it is imperative for the serious physician/scientist to receive in-depth training in a scientific discipline relevant to medicine and that the training of the serious physician/scientist should be comparable to Ph.D. programs in rigor and scope. The physician should not be burdened with clinical responsibilities during the research training period. Smith believes that at least three years of rigorous training in modern biological science is usually necessary for most individuals to achieve independence as an investigator.

Those committee members who are experienced in the training of physician/scientists support Smith's proposal for such a training program and believe it should contain the following elements:

1. The training program should represent a consortium between the clinical and pre-clinical departments of the institution with joint responsibility for design and administration of the program.

2. Selection of the trainees should be made as early in the academic pipeline as possible, even during undergraduate medical education, if possible, but based on evidence of some experience and overall promise in research. Selection planning can then be coordinated for both basic clinical training and for the subsequent scientific training. The basic science departments and/or programs should participate in the selection process so that their commitment to the individual selected is ensured.

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[6]See Lloyd G. Smith, "Training of Physician/Scientists," in Volume III of this report.

3. Formal coursework in the physical and biochemical sciences, as well as in the epidemiological, biostatistical, and economic disciplines, should also be available and applied for an individual investigator as the need for that discipline arises.[7] The committee members who are experienced in the training of physician/scientists recognize that it is important for graduates of this physician/scientist program to command a theoretical background comparable to that obtained by those with graduate degrees in these various disciplines. Clearly, the extent of required coursework must be individualized based upon the level of prior training, but it must be relevant and rigorous at the graduate level.

4. Such a training program in the sciences, above and beyond what is involved in the subspecialty training events, must be for not less than three years, and most of that must be invested in direct research experience under the direct supervision of a mentor. Completion of this training period, which may often be extended beyond the formal three-year program, would allow physician/scientists to rejoin their respective clinical department for subspecialty training in the chosen disciplines. It is recognized that some may elect to remain in basic science and will enrich those disciplines with their breadth of training and interest in human biology.

Those committee members who are experienced in the training of physician/scientists suggest that over the course of a three-year training period, modules of instruction should be specifically tailored to the needs of the physician trainee.[8] This program of study would provide the physician/scientist with enough scientific depth to sustain a research career for a lifetime and not merely for a limited time beyond postdoctoral research training Improved training in the fundamentals should also enable the physician/scientist to develop the flexible approach to problem-solving that is critical for successful pursuit of other lines of investigation stemming from observations made during the course of a goal-oriented research project.

The committee as a whole finds merit in these proposals and recommends that NIH establish a committee, conference, or study to address the central issues concerning the program of study in postgraduate institutional training grants for physician/scientists.

Special Consideration: Health Services Research

Health services research aims to improve the way health care services are delivered through improved use of existing medical technology. It studies the quality, efficacy, and appropriateness of health care services as well as how these are affected by the method of reimbursement, the training of health professionals, and other aspects of the health care delivery system.

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[7]This is consistent with survey results that indicate former postdoctoral research trainees favor changing the curriculum to include more formal coursework and less clinical medicine. See G. Levey et al., "Postdoctoral Research Training of Full-time Faculty in Academic Departments of Medicine," *Annals of Internal Medicine*. vol. 109, no. 5 (September 1988).

[8]These modules could include such topics as basic laboratory techniques, chromatography, radioimmunoassay, protein purification, advanced instrumental techniques, fundamental principles of enzymology and molecular biology, subcellular fractionation techniques, computer technology, evaluation of experimental data, epidemiology, statistics and data base management, as well as grant and manuscript writing.

Health services research is an interdisciplinary activity that requires individuals to be trained in a variety of fields, including medicine, economics, public health, sociology, statistics, psychology, and other fields in the natural and social sciences. In addition, it requires specially trained individuals who are capable of bringing disparate disciplines together to examine questions about the delivery of health services. These individuals receive interdisciplinary training in programs of health services research or public policy analysis. Those whose degree is in a field such as medicine or economics require additional training in the methods and knowledge base of health services research, which is usually received during a postdoctoral period.

Little quantitative information is available about either the supply of or demand for health services researchers, although Elizabeth McGlynn's paper (see Volume III) identifies disciplines for the members of the Association of Health Services Research. The same paper also outlines a research agenda that would provide some important basic information about demand and supply. Because of the interdisciplinary nature of health services research, a study of field migration is central to an understanding of the supply of researchers in the field. How much migration into and out of the field occurs? What factors affect migration rates? How long does it take an in-migrant to become productive? How does migration affect the quality of health services research? A more mundane but nevertheless important evaluation issue is how one should identify a person, a research project, or a training program as being part of the field of health services research.

Although we cannot quantify with much precision the current demand for health services researchers, there is substantial evidence that the demand will increase significantly in the near future. Members of the Congress, the Administration, and the private sector all have expressed a keen interest in obtaining answers to complex questions about controlling the quality and cost of health care. Bills introduced into both the House and Senate would authorize a wide program of health services research activities at a greatly increased level of spending beginning in 1990 (S. 702 would authorize spending $239 million over three years; H. 1692 would authorize $847 million over five years). The Administration has requested increased funding for evaluation research. Many private foundations have been funding pioneering work in this area throughout the last decade, and the insurance industry recently has begun to sponsor research in this area. It seems prudent to increase funding for training in this area so that the research monies will be well spent.

APPENDIX

THE EMERGING BIOTECHNOLOGY INDUSTRY

SUMMARY AND CONCLUSIONS

The 1989 survey of biotechnology firms indicated that strong employment growth is anticipated for Ph.D. biomedical scientists in the near future. Firms appear to be having problems finding scientists trained in pharmacology, toxicology, immunology, human/animal molecular biology, and industrial microbiology. Biochemistry and chemistry are the largest occupational groups, with almost a third of all biotechnology specialists.

By and large, biotechnology firms are very pleased with the formal academic training of scientists. Two major complaints appear to be the poor oral and written communication skills of new graduates and the lack of a "focused" approach to research. Postdoctoral appointments, especially nonacademic appointments, are viewed by industry as valuable additions to the training process. The postdoctoral experience allows the young scientists to prove their ability for independent research and at least partially moves them toward a more focused research approach. The training implications of this are threefold. First, graduate programs need to pay more attention to developing the communication skills of their scientists. Second, industry appears to desire moving the research training toward applied work and away from basic work. Third, industry would like to see postdoctoral appointments continue as an integral part of the training process and would like to see more nonacademic (industry, foundations, etc.) postdoctoral appointments made.

SURVEY DESCRIPTION

In 1988 this committee collaborated with the National Science Foundation (NSF) in a joint effort to collect information on the employment of biomedical scientists in the biotechnology industry and in industry in general (hereafter the National Academy of Sciences [NAS]/NSF survey). The survey frame was developed from a list of dedicated biotechnology firms (DBCs)[1] used in a 1987 Office of Technology Assessment (OTA) biotechnology industry survey and updated from a listing of U.S. biotechnology companies as appeared in the *Seventh Annual Genetic Engineering News (GEN) Guide to Biotechnology Companies.*[2] Of a total of 512 firms queried, 71.3 percent returned usable responses. Based on the assumption of no nonresponse bias, the returned survey tabulations were inflated to represent an estimate of the total survey frame.[3] The following discussion summarizes the results of this estimate.

1989 Employment

Total 1989 employment in DBCs is estimated at 53,985; of this total, 3,527 (6.5 percent) are Ph.D.-level scientists. The total number of scientists employed by DBCs in 1989 was estimated at 8,937 (16.6 percent of total DBC employment); thus, almost 40

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[1]DBCs are those companies whose primary line of work is in the biotechnology field. In addition to these firms, large diversified companies exist that have a biotechnology division or laboratory. In 1987, the Office of Technology Assessment (OTA) estimated that total biotechnology employment in the diversified companies was 11,600 compared to 24,347 in DBCs (see footnote 2).

[2]See Office of Technology Assessment, *New Developments in Biotechnology, Volume 4: U.S. Investment in Biotechnology*, Washington, D.C.: Office of Technology Assessment, 1988, Chapter 8; and *Genetic Engineering News*, vol. 8, no. 10, 1988.

[3]The returned survey results were simply inflated by 1,403, which represents the ratio of total survey frame (512) to usable responses (365).

percent of the scientists employed by DBCs hold a doctoral degree. In the NSF general survey of all industry, 0.5 percent of total employment was composed of Ph.D.s; doctorates made up approximately 25 percent of all employed scientists. Scientists of all degree levels comprised 2.2 percent of total general employment. Not surprisingly, the biotechnology industry is weighted heavily toward a Ph.D. work force, reflecting the research and development nature of its business. In 1989 79.5 percent of the scientists in the DBC survey had R&D as their primary work activity.[4]

Occupational Employment: Table A-1 contains descriptive statistics on the occupational employment of DBCs. The biotechnology areas of molecular genetics (9.6 percent of DBC Ph.D. employment), general microbiology (7.0 percent), human/animal molecular biology (8.8 percent), immunology (6.1 percent), general biochemistry (14.1 percent), and other chemistry (18.3 percent) are the largest occupational groups. All other Ph.D. scientist occupations combined totaled 36 6 percent of DBC Ph.D. employment.

Shortage Occupations: Table A-1 also contains estimates of shortages by occupation. A shortage was defined in the survey as "a vacancy that went unfilled for 90 days or longer, even though you actively sought to fill it." Overall, 5.5 percent of total DBC employment was classified as "shortages." Biotechnology specialties with "large" shortages (defined as 9 percent or more of current employment) included industrial microbiology (9.8 percent), human/animal molecular biology (9.7 percent), pharmacology (11.9 percent), toxicology (17.8 percent), and enzymology (11.9 percent). In terms of total shortages, biochemistry and general chemistry had the most absolute vacancies with 42 and 45, respectively. These findings are somewhat different from those of OTA in its 1987 report. In that report companies reported an ample supply of scientists trained in molecular biology, biochemistry, cell biology, and immunology.[5]

Planned Hires: The DBCs surveyed were asked to estimate the number of Ph.D. scientists that they planned to hire in the 1988-1989 period. These planned hires were for both replacements and new hires. Firms traditionally have been optimistic in estimating future planned growth; however, the planned hires variable does give one an idea of the relative growth among occupations.[6]

Table A-1 contains planned hires as a percent of total employment; this percent thus reflects both growth and replacement. Most of the specialties that are expected to have a high rate of planned hires also are those defined as shortage specialties. Toxicology, industrial microbiology, and other biotechnology specialties all had high rates of planned hires. Overall, the DBCs indicated that they planned to hire 18.8 percent of their current level of scientist employment in 1988-1989. The planned hire rate for engineers is 16.4 percent, which runs counter to recent speculation that the industry is moving away from research (and a rich mix of scientists) toward production (and a rich mix of engineers and technicians). The DBCs surveyed indicated that the most common response to shortages was to increase recruitment efforts (69.8 percent of the firms) and to offer higher salaries (37.4 percent of the firms).

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[4]This compares very favorably with the SDR 1987 survey results that indicated 77.6 percent of Ph.D. biomedical scientists employed by private industry had as a primary work activity R&D or the management of R&D.

[5]Office of Technology Assessment, *New Developments in Biotechnology*, p. 135.

[6]Biotechnology companies reported a 42-percent planned staff increase for the 1983-1984 period; the actual increase was 20 percent. (Office of Technology Assessment, *New Developments in Biotechnology*, p. 133).

EMPLOYMENT GROWTH

The 1987 OTA report estimates 1987 DBC employment at 24,347 overall, with 13,221 scientists and technicians. Large diversified companies were estimated to have another 11,600 workers overall and 5,360 scientists and technicians.[7] The NAS/NSF survey of DBCs estimated a total 1989 employment of 53,985, with 14,534 scientists and technicians. It is likely that most of the difference between the 1987 OTA and the NAS/NSF surveys is explained by the more comprehensive survey frame: the OTA survey queried 296 firms, and the NAS/NSF survey frame was 512. This difference also may explain a portion of the difference in occupational structure (i.e., the OTA survey estimated 54 percent of total employment composed of scientists and technicians, and the NAS/NSF survey estimated 27 percent). If the NAS/NSF frame included firms that engaged in medical services as well as research (blood and urine testing, for example), they would have a smaller portion of their work force research-oriented. Thus, the wider "net" of the NAS/NSF survey may have caught biotechnology firms outside the core of research firms.

However, it is likely that some portion of the difference in the OTA totals and the NAS/NSF totals was due to growth. Planned scientist hires for 1988-1989 because of growth were estimated by the DBCs at 8.7 percent, which is close to the historical rate of private sector growth of Ph.D. biomedical scientist employment of 9.1 percent experienced from 1973-1987. Of firms with scientist job vacancies, 29.2 percent reported more vacancies than the previous year, 45.6 percent reported the same level of scientist vacancies, and 25.2 reported fewer vacancies.

FIRM PERCEPTIONS

In addition to the quantitative data, the NAS/NSF survey selected 40 firms that had large segments of biomedical/behavioral scientist employment for a special follow-up telephone survey. The supervisors of the biomedical and behavioral research scientist work force in these firms were contacted and asked to discuss the two areas summarized below.

1. *How well has the traditional training of scientists prepared them for their careers in industry?* In general, the telephone respondents were very pleased with the quality of academic training that their scientists received. The major complaint that was expressed with newly trained scientists is that they do not have a goal-oriented (or product-oriented) approach to their research. Industrial research requires more "focus" than academic research. Even basic research in industry requires timetables and goals. A second complaint mentioned by several of the telephone respondents was a lack of both oral and written communication skills.

2. *What is the value of postdoctoral training for industrial research scientists?* Almost without exception, the telephone respondents felt that the postdoctoral experience was a very important "seasoning" process for their scientists. Firms actively sought out postdoctorates for hiring, and they were more than willing to pay a salary premium for scientists with postdoctoral experience.

In view of the comments in question 1 above, it appears that the postdoctorate works as a screening mechanism that allows a newly minted Ph.D. to prove his/her ability for independent research. A postdoctoral appointment in industry as opposed to an academic setting is preferred.

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[7]See Office of Technology Assessment, *New Developments in Biotechnology*, Table 8-1.

DATA NEEDS FOR PROGRAM EVALUATION

To assess the numerical adequacy of the nation's biomedical and behavioral research personnel and to make judgments about the quality of their training, we need both quantitative and qualitative information. Timely, accurate, and relevant information is essential to the success of this effort. A number of data sets are maintained by NIH and other federal agencies that are directly relevant to the responsibilities of the Committee on Biomedical and Behavioral Research Personnel. Unfortunately, some of the sets are complex and difficult to manipulate. Even when one manages to retrieve information from them, the information's quality is sometimes questionable. We propose to extract from them and from other sources a data set that is tailored to the information needs of this committee and potentially to those of NIH.

The proposed "evaluation data matrix" could form the core of a management information system for use in tracking and evaluating the National Research Service Award (NRSA) program. The difficulties encountered by this committee in simply attempting to correlate the historical levels of prior committee recommendations with actual NRSA awards by field suggest that this tracking has been difficult at best. What is needed is a coordinated systematic data set that provides descriptive and comparative statistics relevant to the committee. It should be coordinated and systematic in its use of common taxonomies and measures that satisfy the needs of the committee. It should be descriptive of programs at a level of detail that the committee deems appropriate, providing information about characteristics, both of the programs and of their participants, and it should be comparative across programs and through time.

The needed data set can be conceptualized simply as a time series of matrices whose rows represent program categories (or "activity codes," as they are called by NIH) such as F31: predoctoral individual NRSA fellowship. The columns represent characteristics of the programs and their participants. For example, one of the nine program characteristics requested was median length of training time. Thus, a cell in this column would represent the median training time of the program type that the particular row represents. Primarily for the benefit of future versions of our committee, we have undertaken an initial design and pilot construction of such a data matrix. Our design of both rows and columns is shown below.

In order to gain an idea of the magnitude and feasibility of the project, we contracted with a firm that is experienced in working with the relevant data bases to undertake a pilot construction.

Results: The contracted firm concluded that, while some items of the data matrix could be constructed fairly readily, others would involve a greater level of effort to construct. In principle, at least, data exist with which to construct all cells of the 39 by 20 matrix. The exercise revealed several important problems, most of which the committee had been aware. The five most important problems with the existing data sets are described briefly in the following section.

Problems in the Data Sets: The data sets are subject to a number of criticisms, five of which are most serious for our purposes.

1. *Access*: Since our study was located in NAS/NRC's Office of Scientific and Engineering Personnel (OSEP), which also houses the Survey of Earned Doctorates (SED) and SDR, there was no problem in accessing these data. However, there are some difficulties in accessing the major NIH data sets. Although our staff have direct accessing abilities, it appears preferable to work through the NIH staff. The Information for Management, Planning, Analysis and Coordination (IMPAC) file is the primary source of financial

and other data on Public Health Service (PHS) extramural programs; data are organized by fiscal year. The Information Systems Branch of the Division of Research Grants (DRG) responds to requests for data regarding these PHS activities. In addition, DRG provides annual data that are used by the National Research Council (NRC) to update the Trainee Fellow File (TFF) and Consolidated Grant Applicant File (CGAF). These two files are organized by individual recipients of traineeships, fellowships, or grants. Data derived by DRG from the IMPAC file are considered to be "official" data, while data derived by others from TFF and CGAF may be considered for some purposes to be "unofficial." A written request for data to be extracted from the IMPAC file was sent on behalf of the committee to DRG. Some materials were received from DRG, although most were not at the level of detail needed for the data matrix. Some unofficial data were extracted by the contracted firm from the TFF and CGAF files and provided to the committee, forming the basis of the statistical profile of training programs in Chapter 2.

2. *Quality of CGAF and TFF files*: These two files rearrange the IMPAC information to identify all the training received by a single individual (TFF) and all the research grants given to an individual principal investigator (CGAF). This information is essential for the committee to determine the subsequent research participation of those who have received NRSA research training and to do longitudinal studies of participation in NRSA research. Some concerns have been expressed by DRG and NIH about the quality of these two data sets. Thus, we recommend that NIH evaluate the accuracy of a sample of the data sets.

3. *Classification of race/ethnicity and sex*: Apparently there are problems of nonreporting and incorrect reporting of gender and race/ethnicity data on the IMPAC file. A representative of DRG discourages the use of these data. This is most discouraging in light of the clear need to monitor progress of women and minorities in science. We recommend further investigation of data quality, including the matching of individuals across sources of data and over time in an effort to resolve inconsistent reporting of data.

4. *Classification of training field*: The definition of fields of science presents several problems. The Discipline/Specialty/Field (D/S/F) codes in the IMPAC file apparently have not been coded consistently across the various institutes of NIH and ADAMHA. The DRF, derived from the SED, provides data only for Ph.D.s and does not take into account persons with degrees in one field who are receiving additional training in another. The D/S/F codes need additional investigating; it may be the case that they provide sufficiently accurate data at the broad field levels of biomedical sciences and behavioral sciences, but we cannot be certain without further investigation. We strongly recommend that NIH investigate the accuracy of this classification and, if necessary, design better centralized quality control methods and apply them to these classifications.

5. *Response rates in the SDR*: These rates have been extremely low for many years, varying across fields from the high 40s to the low 70s. We recognize the complexities and problems of attrition in a longitudinal data set such as this but recommend that ways be found to improve the rates. An NAS panel on the NSF data system, of which the SDR is a part, recently has made a

similar recommendation.[8] We understand that a study of nonresponse bias in the SDR currently is under way within NAS/NRC and await its results with interest.

[8]C. F. Citro and G. Kolton (eds.), *Surveying the Nation's Scientists and Engineers: a Data System for the 1990s*, Washington, D.C.: National Academy Press, 1989.

Preliminary List of Evaluation Data Matrix
Rows: Program Categories

1. Basic Biomedical Science
   a. Predoctoral
      o Individual
         oo NRSA Fellowships
         oo Other
      o Institutional
         oo MARC Undergraduate
         oo NRSA Traineeships
         oo Other
   b. Postdoctoral
      o Individual
         oo NRSA Fellowships
         oo Career Development Awards (K07, K08)
         oo Other
      o Institutional
         oo NRSA Traineeships
         oo Other

2. Behavioral Sciences
   a. Predoctoral
      o Individual
         oo NRSA Fellowships
         oo Other
      o Institutional
         oo MARC Undergraduate
         oo NRSA Traineeships
         oo Other
   b. Postdoctoral
      o Individual
         oo NRSA Fellowships
         oo Career Development Awards (K07, K08)
         oo Other
      o Institutional
         oo NRSA Traineeships
         oo Other

3. Clinical Sciences
   a. Predoctoral
      o Individual
         oo NRSA Fellowships
         oo Other
      o Institutional
         oo NRSA Traineeships
         oo Other
   b. Postdoctoral
      o Individual
         oo NRSA Fellowships
         oo Career Development Awards (KXX series, including K11, K15)
         oo Other
      o Institutional
         oo NRSA Traineeships
         oo Other

PRELIMINARY LIST OF MATRIX COLUMNS: CHARACTERISTICS OF PROGRAMS AND PARTICIPANTS

1. Program characteristics in given year

   a. Goals
   b. Number of institutions involved
   c. Number of recipients
   d. Median length of training
   e. Total enrollment
   f. Total cost
   g. Cost per recipient month
   h. Median number of trainees per institution
   i. Publication counts of faculty in primary department(s) of program

2. Participant characteristics in given year (median, except as noted)

   a. Baccalaureate selectivity scores (A. Astin)
   b. Quality rating (NRC, 1982) of doctoral department
   c. Quality rating of primary department in postdoctoral programs
   d. GRE scores
   e. Percent female
   f. Percent Asian/Pacific Islander
   g. Percent other minority
   h. Number of publications in first K postdoctoral years
   i. Number of citations in first K postdoctoral years
   j. Percent who apply for research grants in first K post-doctoral years
   k. Percent who receive research grants in first K post-doctoral years
   l. Percent in academia K years after termination of training

SUMMARY OF EMPLOYMENT TRENDS

Table A-1. Occupational Employment in Dedicated Biotechnology Companies, 1989

Occupation	Total Employed	Total Employed Ph.D.s	Shortage as % of Employed	Planned Hires as % of Employed
BIOTECHNOLOGY SPECIALTIES				
Molecular Genetics	724	340	2.7%	13.8%
Classical Genetics	42	20	5.1%	15.3%
Industrial Microbiology	311	72	9.8%	29.3%
General Microbiology	665	248	1.2%	10.1%
Human/Animal Cell Biology	471	198	3.0%	10.1%
Plant Cell Biology	86	45	4.5%	13.4%
Human/Animal Molecular Biology	508	309	9.7%	21.7%
Plant Molecular Biology	90	55	3.7%	11.0%
Human/Animal Biology	246	87	3.4%	11.5%
Plant Biology	42	25	4.0%	15.8%
Pharmacology	209	[illegible]	11.9%	25.9%
Toxicology	73	17	17.8%	29.7%
Enzymology	81	59	11.9%	27.2%
Immunology	532	216	7.9%	20.8%
other biology	154	39	2.5%	15.3%
Analytical Biochemistry	377	156	3.9%	20.5%
General Biochemistry	1042	498	6.0%	17.7%
Other Chemistry	1397	644	5.0%	21.7%
Other Biotechnology Specialties	369	163	3.7%	43.0%
TOTAL	7420	3282	5.4%	19.4%
OTHER SCIENTISTS				
Medical Science, MD	66	0	0.0%	0.0%
Medical Science, non MD	104	18	0.0%	65.8%
Health Physics	3	0	0.0%	0.0%
Agricultural Sciences	73	27	3.8%	3.8%
Other Physical Sciences	191	43	11.5%	16.1%
Behavioral/Social Sciences	310	67	3.0%	3.0%
Computer Sciences	655	59	1.7%	1.7%
Mathematics	115	31	22.7%	16.2%
TOTAL	1517	246	6.5%	11.4%
TOTAL SCIENTISTS	8937	3527	5.5%	18.8%
ENGINEERS				
Biochemical Engineer	170	0	9.1%	30.6%
Bioengineer	279	0	14.6%	25.6%
Bioprocess Engineer	115	0	3.7%	50.0%
Other Engineers	2337	0	2.0%	12.4%
TOTAL ENGINEERS	2901	0	3.7%	16.4%
TOTAL TECHNICIANS	5597	0	3.6%	19.4%
OTHER EMPLOYMENT	36550			
TOTAL EMPLOYMENT	53985			

NOTE: Shortages and new hires for engineers and technicians are computed on total employment; for scientists the base is Ph.D. employment. Shortages are defined as unfilled vacancies for 90 days or longer.

SOURCE: NSF Survey of Dedicated Biotechnology Companies, 1989.

Table A-2. Total and R&D Employment by Employment Sector, 1973-1987, Biomedical Scientists

Year	Total	Aca-demic	Post-doc	Labs	Govn	Indus	Self-Empl	Hosp	Non-profit	Other
Total										
1973	43244	25471	3607	1031	4338	5369	518	1431	1293	186
1975	50088	28332	5369	994	4517	6662	840	1948	1232	194
1977	54234	30384	6312	1040	4568	6893	862	2297	1543	335
1979	61649	33566	7268	1079	5080	8455	1178	2726	1858	439
1981	68039	36482	8026	1236	5398	9928	1857	2799	2088	225
1983	70471	36963	7827	661	5988	11819	1910	2946	2102	255
1985	78687	41032	8364	783	6479	13706	2254	3307	2460	302
1987	84434	43025	8172	909	7049	15928	2634	3629	2651	437
Growth	4.9%	3.8%	6.0%	-0.9%	3.5%	8.1%	12.3%	6.9%	5.3%	6.3%
R&D										
1973	23188	9915	3403	926	3094	4110	20	648	1013	58
1975	25955	10292	4776	933	3107	4949	53	861	954	32
1977	29378	12523	5590	977	2936	5084	45	1035	1146	42
1979	34554	15015	6103	916	3321	6247	110	1383	1404	56
1981	38807	16628	7183	1130	3529	7196	126	1272	1723	20
1983	39034	16910	6828	621	3608	8283	207	1031	1529	17
1985	43595	19607	6924	698	3818	9382	283	1092	1780	11
1987	51110	22751	7346	746	4670	12359	328	1143	1749	19
Growth	5.8%	6.1%	5.6%	-1.5%	3.0%	8.2%	22.1%	4.1%	4.0%	-7.6%
Percent R&D										
1973	53.6%	38.9%	94.4%	89.8%	71.3%	76.5%	3.9%	45.3%	78.4%	30.9%
1975	51.8%	36.3%	88.9%	93.8%	68.8%	74.3%	6.3%	44.2%	77.4%	16.5%
1977	54.2%	41.2%	88.6%	93.9%	64.3%	73.8%	5.2%	45.0%	74.3%	12.6%
1979	56.0%	44.7%	84.0%	84.9%	65.4%	73.9%	9.3%	50.7%	75.5%	12.7%
1981	57.0%	45.6%	89.5%	91.4%	65.4%	72.5%	6.8%	45.4%	82.5%	8.9%
1983	55.4%	45.7%	87.2%	93.9%	60.3%	70.1%	10.8%	35.0%	72.7%	6.7%
1985	55.4%	47.8%	82.8%	89.1%	58.9%	68.4%	12.6%	33.0%	72.4%	3.7%
1987	60.5%	52.9%	89.9%	82.1%	66.2%	77.6%	12.5%	31.5%	66.0%	4.4%

SOURCE: 1973-1987 Survey of Doctorate Recipients.

Table A-3. Total and R&D Employment by Employment Sector, 1973-1987, Nonclinical Psychologists

Year	Total	Academic	Postdoc	Labs	Govn	Indus	Self-Empl	Hosp	Nonprofit	Other
Total										
1973	13159	9452	259	0	1083	999	323	269	562	212
1975	15209	10863	396	0	1170	1218	401	470	560	129
1977	15711	10905	394	0	1404	134[illegible]	443	447	519	255
1979	16314	11538	527	0	1164	1355	321	401	574	434
1981	18496	12586	511	0	1235	1826	905	507	631	295
1983	19025	12404	302	0	1320	2258	1328	629	451	333
1985	19694	13221	593	0	1189	1924	1270	585	667	245
1987	20510	13058	666	0	1724	1745	1655	555	858	249
Growth	3.2%	2.3%	7.0%		3.4%	4.1%	12.4%	5.3%	3.1%	1.2%
R&D										
1973	4127	2072	251	0	657	464	47	119	416	101
1975	4310	1847	364	0	825	584	51	209	392	38
1977	4656	2106	348	0	909	740	16	188	297	52
1979	5383	2809	442	0	830	694	32	160	339	77
1981	5390	2750	369	0	748	838	128	162	396	0
1983	5028	2619	262	0	650	890	215	146	216	29
1985	5040	2566	356	0	678	897	157	125	224	37
1987	6135	3086	561	0	1013	752	137	105	412	69
Growth	2.9%	2.9%	5.9%		3.1%	3.5%	8.0%	-0.9%	-0.1%	-2.6%
Percent R&D										
1973	31.4%	21.9%	96.9%	0.0%	60.7%	46.4%	1[illegible].5%	44.3%	74.0%	47.5%
1975	28.3%	17.0%	91.4%	0.0%	70.5%	48.0%	2.7%	44.5%	70.0%	29.7%
1977	29.6%	19.3%	88.3%	0.0%	64.7%	55.1%	3.6%	42.1%	57.1%	20.6%
1979	33.0%	24.3%	84.0%	0.0%	71.3%	51.2%	10.0%	40.0%	59.1%	17.7%
1981	29.1%	21.9%	72.2%	0.0%	60.5%	45.9%	14.1%	31.9%	62.8%	0.0%
1983	26.4%	21.1%	86.7%	0.0%	49.3%	39.4%	16.2%	23.2%	48.0%	8.7%
1985	25.6%	19.4%	60.0%	0.0%	57.0%	46.6%	12.3%	21.4%	33.6%	15.0%
1987	29.9%	23.6%	84.2%	0.0%	58.7%	43.1%	8.3%	19.0%	48.0%	27.8%

SOURCE: 1973-1987 Survey of Doctorate Recipients.

Table A-4. Total and R&D Employment by Employment Sector, 1973-1987, Other Behavioral Sciences

Year	Total	Academic	Postdoc	Labs	Govn	Indus	Self-Empl	Hosp	Nonprofit	Other
Total										
1973	6689	6135	98	0	121	42	52	12	187	42
1975	8351	7621	151	0	210	21	55	41	238	14
1977	10322	9239	246	0	311	40	81	46	306	53
1979	11127	9568	282	0	453	129	103	54	497	41
1981	11019	9477	199	0	463	57	183	37	457	146
1983	12749	11002	271	0	385	128	380	218	249	116
1985	12945	11009	256	0	218	193	466	373	304	126
1987	12928	10767	192	0	379	229	455	408	346	152
Growth	4.8%	4.1%	4.9%		8.5%	12.9%	16.8%	28.6%	4.5%	9.6%
R&D										
1973	1309	934	98	0	81	20	28	12	125	11
1975	1557	1062	116	0	150	9	12	15	188	4
1977	2171	1455	206	0	193	20	23	14	251	9
[illegible]	2680	1653	200	0	297	81	14	10	411	15
1981	2333	1403	111	0	428	12	4	11	336	28
1983	2065	1456	161	0	179	2	45	9	151	62
1985	1967	1479	115	0	126	21	52	47	113	12
1987	2539	1688	136	0	232	147	78	74	177	8
Growth	4.8%	4.3%	2.4%		7.8%	15.3%	7.7%	13.9%	2.5%	-2.2%
Percent R&D										
1973	19.6%	15.2%	100.0%	0.0%	67.3%	47.6%	53.3%	100.0%	66.9%	25.7%
1975	18.6%	13.9%	77.0%	0.0%	71.6%	42.9%	22.6%	35.7%	79.0%	28.6%
1977	21.0%	15.8%	83.9%	0.0%	61.9%	50.0%	28.4%	30.4%	82.0%	16.7%
1979	24.1%	17.3%	71.1%	0.0%	65.5%	62.7%	13.6%	18.5%	82.7%	35.6%
1981	21.2%	14.8%	55.9%	0.0%	92.4%	21.1%	2.2%	29.7%	73.5%	18.9%
1983	16.2%	13.2%	59.3%	0.0%	46.5%	1.7%	12.0%	4.0%	60.5%	53.2%
1985	15.2%	13.4%	44.9%	0.0%	57.9%	11.0%	11.1%	12.7%	37.3%	9.9%
1987	19.6%	15.7%	70.8%	0.0%	61.1%	64.0%	17.1%	18.2%	51.1%	5.2%

SOURCE: 1973-1987 Survey of Doctorate Recipients.

Table A-5. Educational Achievements, 1975-1988, by Race (Numbers in Thousands)

	Black	Percent Loss	White	Percent Loss
18-year-olds, 1975[1]	559		3,684	
H.S. Dropouts aged 18 in 1975[2]	142	25.4	542	14.7
H.S. Graduates, 1975	417		3,142	
Freshmen, 1975[3]	80	80.8	1,065	66.1
Baccalaureates, 1979[4]	60	25.0	803	24.6
Ph.D.s, 1988[5]	0.81	98.7	23	97.1

SOURCES: (1) American Council on Education (ACE), 1981-81 Fact Book for Academic Administrators, Washington, D.C.: ACE, 1981, Table 5.
(2) National Center for Educational Statistics (NCES), Digest of Educational Statistics of Educational Statistics, 1988, NCES, Washington, D.C.: 1988, Table 80.
(3) ACE, op. cit., estimated from Tables 95 and 136.
(4) NCES, op. cit., Table 182.
(5) NAS/NRC, Doctorate Record File.

Table A-6. Estimates of Losses at Selected Points in the Academic Pipelines into Biomedical and Behavioral Science

	Numbers		Percent Loss	
	Biomedical	Behavioral	Biomedical	Behavioral
1980 Freshmen	97100	172600		
1984 B.A./B.S.	37100	58600	61.8	66.0
1977-1979 1st Yr. Graduates	8451	9477	77.2	83.8
1985-1987 Ph.D.s	3970	4000	57.8	64.6

SOURCES: 1980 freshmen from Astin, A.W. et al., The American Freshman: National Norms for Fall, 1980, Los Angeles: Higher Education Research Institute, University of California at Los Angeles, 1980). All other sources are from Volume II of this report, Summary Tables 2 and 3.

Table A-7. NIH Trainees/Fellows By Years Since Initiation of NRSA Research Training, R01 Grant Activity and Degree Type

Years Since Init. of NRSA Research Training	Total	R01 Grant Applicants and Recipients			
		Applicants		Recipients	
		Number	Percent	Number	Percent
M.D. Postdoctoral Fellows:					
10	139	81	58.3%	45	32.4%
9	138	69	50.0%	43	31.2%
8	129	56	43.4%	34	26.4%
7	153	61	39.9%	27	17.6%
6	131	45	34.4%	26	19.8%
5	120	34	28.3%	15	12.5%
Ph.D. Postdoctoral Fellows:					
10	779	424	54.4%	291	37.4%
9	669	339	50.7%	231	34.5%
8	773	395	51.1%	251	32.5%
7	764	325	42.5%	199	26.0%
6	669	243	36.3%	144	21.5%
5	505	144	28.5%	82	16.2%
M.D. Postdoctoral Trainees:					
10	451	150	33.3%	94	20.8%
9	658	181	27.5%	91	13.8%
8	793	189	23.8%	90	11.3%
7	884	158	17.9%	87	9.8%
6	865	124	14.3%	62	7.2%
5	909	77	8.5%	34	3.7%
Ph.D. Postdoctoral Trainees:					
10	742	320	43.1%	201	27.1%
9	909	404	44.4%	223	24.5%
8	1086	398	36.6%	207	19.1%
7	1116	354	31.7%	179	16.0%
6	1044	248	23.8%	125	12.0%
5	1047	213	20.3%	108	10.3%

SOURCE: Quantum Research Corporation.

Table A-8. Historical and Projected Job Openings and Ph.D. Supply in the Biomedical Sciences, 1973-1995

Year	Employ-ment	Death and Retire-ment	Net Mobility	Growth	Total Openings	PhD Output	Vacancy Ratio	Refresh-ment Rate	Attrition Rate
Historical									
1973	39637								
1974	42101	645	396	2464	3506	3417	1.03	0.086	0.026
1975	44719	691	421	2618	3730	3515	1.06	0.083	0.026
1976	46293	740	447	1574	2761	3578	0.77	0.080	0.027
1977	47922	773	463	1629	2865	3465	0.83	0.075	0.027
1978	51049	806	479	3127	4413	3518	1.25	0.073	0.027
1979	54381	866	510	3332	4708	3644	1.29	0.071	0.027
1980	57128	930	544	2747	4220	3823	1.10	0.070	0.027
1981	60013	985	571	2885	4441	3846	1.15	0.067	0.027
1982	61314	1043	600	1301	2944	3960	0.74	0.066	0.027
1983	62644	1074	613	1330	3017	3788	0.80	0.062	0.028
1984	66373	1106	626	3729	5461	3902	1.40	0.062	0.028
1985	70323	1181	664	3950	5795	3787	1.53	0.057	0.028
1986	73232	1261	703	2909	4873	3864	1.26	0.055	0.028
1987	76262	1323	732	3030	5085	3969	1.28	0.054	0.028
Projected (Mid-Case Scenario)									
1988	80240	1388	763	3978	6129	3969	1.54	0.052	0.028
1989	82330	1460	802	2090	4353	3969	1.10	0.049	0.028
1990	85870	1564	823	3540	5927	3969	1.49	0.048	0.029
1991	88880	1582	859	3010	5451	3969	1.37	0.046	0.028
1992	91990	1593	889	3110	5592	3969	1.41	0.045	0.028
1993	95360	1601	920	3370	5891	3969	1.48	0.043	0.027
1994	98720	1788	954	3360	6102	3969	1.54	0.042	0.029
1995	102460	1816	987	3740	6543	3969	1.65	0.040	0.028

SOURCE: Historical employment data are from Appendix Table A-2; historical Pn.D. data are from Table B3 of Volume II. All other values estimated by NRC.

Table A-9. Historical and Projected Job Openings and Ph.D. Supply in Nonclinical Psychology, 1973-1995

Year	Employ-ment	Death and Retire-ment	Net Mobility	Growth	Total Openings	PhD Output	Vacancy Ratio	Refresh-ment Rate	Attrition Rate
Historical									
1973	6591					1084			
1974	7352	94	198	761	1052	1152	0.91	0.175	0.044
1975	8200	110	221	848	1179	1187	0.99	0.161	0.045
1976	9090	129	246	890	1265	1307	0.97	0.159	0.046
1977	10076	150	273	986	1409	1256	1.12	0.138	0.047
1978	10453	174	302	377	853	1152	0.74	0.114	0.047
1979	10845	188	314	392	893	1154	0.77	0.110	0.048
1980	10832	203	325	-13	516	1094	0.47	0.101	0.049
1981	10820	211	325	-12	523	1114	0.47	0.103	0.049
1982	11619	219	325	799	1343	1030	1.30	0.095	0.050
1983	12478	243	349	859	1451	1011	1.43	0.087	0.051
1984	12583	271	374	105	750	954	0.79	0.076	0.052
1985	12689	282	377	106	766	913	0.84	0.073	0.052
1986	12712	294	381	23	698	955	0.73	0.075	0.053
1987	12736	304	381	24	709	882	0.80	0.069	0.054
Projected (Mid-Case Scenario)									
1988	12900	308	395	164	867	882	0.98	0.069	0.055
1989	13070	312	400	170	882	882	1.00	0.068	0.055
1990	13260	303	410	190	903	882	1.02	0.067	0.055
1991	13470	293	394	210	897	882	1.02	0.067	0.052
1992	13700	286	382	230	898	882	1.02	0.065	0.050
1993	13950	283	373	250	906	882	1.03	0.064	0.048
1994	14220	297	389	270	956	882	1.08	0.063	0.049
1995	14510	307	405	290	1002	882	1.14	0.062	0.050

SOURCE: Historical employment data are from Appendix Table A-4; historical Ph.D. data are from Table C10 of Volume II. All other values estimated by NRC.

Table A-10. Historical and Projected Job Openings and Ph.D. Supply in Other Behavioral Sciences, 1973-1995

Year	Employ-ment	Death and Retire-ment	Net Mobility	Growth	Total Openings	PhD Output	Vacancy Ratio	Refresh-ment Rate	Attrition Rate
Historical									
1973	12900								
1974	13823	184	387	923	1494	1537	0.97	0.119	0.044
1975	14811	208	415	988	1611	1607	1.00	0.116	0.045
1976	15062	233	444	251	929	1590	0.58	0.107	0.046
1977	15317	249	452	255	956	1637	0.58	0.109	0.047
1978	15550	264	460	233	957	1591	0.60	0.104	0.047
1979	15787	280	467	237	983	1582	0.62	0.102	0.048
1980	16850	296	474	1063	1832	1517	1.21	0.096	0.049
1981	17985	328	506	1135	1968	1615	1.22	0.096	0.049
1982	18350	363	540	365	1268	1477	0.86	0.082	0.050
1983	18723	384	551	373	1308	1545	0.85	0.084	0.051
1984	18911	406	562	188	1156	1504	0.77	0.080	0.052
1985	19101	424	567	190	1181	1393	0.85	0.074	0.052
1986	19469	443	573	368	1384	1367	1.01	0.072	0.053
1987	19844	465	584	375	1425	1366	1.04	0.070	0.054
Projected (Mid-Case Scenario)									
1988	20030	470	556	186	1211	1366	0.89	0.069	0.052
1989	20220	474	566	190	1230	1366	0.90	0.068	0.052
1990	20400	471	634	180	1285	1366	0.94	0.068	0.055
1991	20600	455	606	200	1261	1366	0.92	0.067	0.052
1992	20790	444	583	190	1217	1366	0.89	0.066	0.050
1993	21000	438	564	210	1212	1366	0.89	0.066	0.048
1994	21210	460	581	210	1251	1366	0.92	0.065	0.050
1995	21420	474	599	210	1283	1366	0.94	0.064	0.051

SOURCE: Historical employment data are from Appendix Table A-3; historical Ph.D. data are from Table C10 of Volume II. All other values estimated by NRC.

Table A-11. Trends in NIH/ADAMHA M.D. Postdoctoral Trainees/Fellows and Full-Time Faculty in Clinical Departments, 1977-1987

Year	Number of Trainees/ Fellows	Full-Time Clinical Faculty
1961	2770	7201
1962	3871	7698
1963	4220	8909
1964	4587	9474
1965	4921	10649
1966	5081	11447
1967	4968	13420
1968	5189	15654
1969	5222	15986
1970	5030	16806
1971	4572	19256
1972	4401	21456
1973	4314	23884
1974	3543	24950
1975	3127	26846
1976	2918	28603
1977	2203	30349
1978	1879	32622
1979	1780	34057
1980	1906	36665
1981	1938	37716
1982	2026	40148
1983	2108	41938
1984	2184	43443
1985	2265	45007
1986	2162	47193
1987	NA	48834

SOURCE: Computed from the NIH Trainee and Fellow File (TFF) and the American Association of Medical Colleges Faculty Roster.

Table A-12. Biomedical and behavioral Doctorate Recipients,[1] 1978-1982 and 1983-1987 Reporting NIH as Primary Source of Graduate School Support

	1978-1982			1983-1987		
	Total Known	Percent NIH Support	Percent Deviation[2]	Total Known	Percent NIH Support	Percent Deviation[2]
Biomedical Doctorate Recipients						
Men						
Asian	539	15.53	-6.84	487	19.10	-4.16
Black	131	14.50	-7.92	146	13.01	-10.25
Other	137	13.87	-8.55	170	15.29	-7.97
White	9770	22.37	-0.05	8357	23.85	0.59
Women						
Asian	294	18.37	-4.06	352	15.91	-7.35
Black	112	12.50	-9.92	118	13.56	-9.70
Other	57	24.56	2.14	128	21.88	-1.39
White	3771	24.69	2.27	4678	24.09	0.83
Total	14811	22.42	4.63[3]	14436	23.26	4.23[3]
Behavioral Doctorate Recipients						
Men						
Asian	136	3.68	-1.78	130	5.38	2.45
Black	298	6.04	0.59	241	4.15	1.22
Other	262	2.67	-2.78	264	4.17	1.23
White	9345	5.54	0.09	7336	2.41	-0.52
Women						
Asian	138	5.07	-0.38	144	4.17	1.23
Black	350	4.29	-1.17	374	4.01	1.08
Other	153	4.58	-0.88	286	4.90	1.96
White	6829	5.54	0.08	7665	3.16	0.23
Total	17511	5.45	1.04[3]	16440	2.93	0.87[3]

(1) Includes only U.S. citizens and aliens with permanent visas.
(2) Row percent minus total percent.
(3) Standard deviation of the column.

SOURCE: NRC Doctorate Record File.

Table A-13. Biomedical and Behavioral Doctorate Recipients,[1] 1978-1982 and 1983-1987 Reporting Definite Postdoctoral Plans

	1978-1982			1983-1987		
	Total Known	Percent Reporting Plans	Percent Deviation[2]	Total Known	Percent Reporting Plans	Percent Deviation[2]
Biomedical Doctorate Recipients						
Men						
Asian	567	88.18	-1.42	540	86.67	-1.79
Black	146	82.19	-7.41	161	75.16	-13.30
Other	144	87.50	-2.11	192	91.67	2.06
White	10032	90.90	1.29	8914	90.46	2.01
Women						
Asian	310	82.58	-7.02	383	80.94	-7.52
Black	116	83.62	-5.98	122	75.41	-13.05
Other	60	85.00	-4.61	139	76.98	-12.63
White	3941	87.67	-1.94	4980	86.59	-1.87
Total	15316	89.61	2.89[3]	15431	88.46	6.25[3]
Behavioral Doctorate Recipients						
Men						
Asian	151	72.85	-8.28	145	73.10	-6.11
Black	344	82.27	1.14	276	76.09	-3.12
Other	278	83.81	-5.79	286	78.67	-10.93
White	9790	83.01	1.89	7928	81.56	2.35
Women						
Asian	147	65.31	-15.82	167	67.07	-12.14
Black	392	82.14	1.02	410	77.32	-1.89
Other	163	80.36	-9.25	325	76.92	-12.68
White	7088	78.82	-2.30	8187	77.60	-1.61
Total	18358	81.13	5.85[3]	17724	79.21	5.25[3]

(1) Includes only U.S. citizens and aliens with permanent visas.
(2) Row percent minus total percent.
(3) Standard deviation of the column.

SOURCE: NRC Doctorate Record File.

Table A-14. Doctoral Biomedical and Behavioral Scientists Aged 35 and Younger, 1977 and 1987, Reporting Current Postdoctoral Study[1]

	1977			1987		
	Total Known	Percent Postdoc Study	Percent Deviation[2]	Total Known	Percent Postdoc Study	Percent Deviation[2]
Doctoral Biomedical Scientists						
Men						
Asian	756	40.34	15.79	996	19.38	-11.29
Black	84	34.52	9.97	129	63.57	32.89
Other	148	27.70	3.15	246	33.33	2.66
White	12681	21.65	-2.91	10029	30.26	-0.41
Women						
Asian	334	50.30	25.74	563	38.54	7.87
Black	45	26.67	2.11	56	25.00	-5.67
Other	31	16.13	-8.43	100	39.00	8.33
White	2955	29.71	5.16	4437	31.91	1.24
Total	17034	24.56	10.07[3]	16556	30.67	12.37[3]
Doctoral Behavioral Scientists						
Men						
Asian	85	3.53	-0.87	124	4.03	-0.02
Black	111	0.90	-3.50	77	18.18	14.13
Other	143	22.38	17.98	167	8.98	4.93
White	8649	3.98	-0.42	4624	4.35	0.30
Women						
Asian	66	9.09	4.69	108	9.26	5.21
Black	96	6.25	1.85	216	4.17	0.12
Other	31	0.00	-4.40	139	6.47	2.43
White	3280	4.76	0.36	4155	3.03	-1.02
Total	12461	4.40	6.62[3]	9610	4.05	4.65[3]

(1) Excludes those reporting retired or not reporting.
(2) Row percent minus total percent.
(3) Standard deviation of the column.

SOURCE: NRC Survey of Earned Doctorates.

Table A-15. Doctoral Biomedical and Behavioral Scientists, 1977 and 1987, Reporting Full-time Employment in Science or Engineering[1]

	1977			1987		
	Total Known	Percent NIH Support	Percent Deviation[2]	Total Known	Percent NIH Support	Percent Deviation[2]
Biomedical Doctorate Recipients						
Men						
Asian	2134	95.97	4.18	5371	98.42	6.16
Black	484	95.04	3.25	751	94.41	2.15
Other	507	87.38	-4.41	911	96.93	4.67
White	37766	94.60	2.81	54491	94.48	2.22
Women						
Asian	437	77.35	-14.44	1407	86.14	-6.12
Black	115	86.09	-5.70	298	81.88	-10.38
Other	75	64.00	-27.79	247	85.43	-6.84
White	6423	75.39	-16.40	13756	81.60	-10.66
Total	47941	91.79	10.67[3]	77232	92.26	6.43[3]
Behavioral Doctorate Recipients						
Men						
Asian	427	97.89	7.68	779	93.58	8.02
Black	320	89.06	-1.15	722	91.41	5.85
Other	308	93.83	3.62	841	90.61	5.05
White	29798	94.55	4.34	40013	91.02	5.46
Women						
Asian	137	88.32	-1.89	405	72.10	-13.46
Black	215	84.65	-5.56	678	86.58	1.02
Other	92	80.43	-9.77	433	75.06	-10.50
White	9215	76.00	-14.21	20502	74.64	-10.92
Total	40512	90.21	6.97[3]	64373	85.56	8.32[3]

(1) Excludes those reporting retired or not reporting.
(2) Row percent minus total percent.
(3) Standard deviation of the column.

SOURCE: NRC Survey of Earned Doctorates.

Table A-16. Death and Retirement Rates

Biological Age	Retirement Rate	Death Rate
<30	0	0.0011
30-34	0	0.0017
35-39	0	0.0027
40-44	0	0.0038
45-49	0	0.0063
50-54	0	0.0114
55-59	0.0026	0.0179
60-64	0.0753	0.0271
65-69	0.1714	0.0378
>=70	1	0.05

SOURCE: Charlotte V. Kuh and Roy Radner, Mathematicians in Academia: 1975-2000, A Report to the National Science Foundation, Washington, D.C.: Conference Board of the Mathematical Sciences, 1980, pp. 84-86.

Table A-17. Estimated Quit Rates for Biomedical Scientists, 1983-1987

Career Age	(1) Biomed.	(2) Biomed. RD & Mgt.RD	(3) Postdoc Biomed.	(4) Retired	(5) Total PhDs	(6) Total PhDs -Retired	(7) Bio. Sci. per 1000 Sci.	(8) Annual Quits (%)	(9) Annual R&D Quits (%)
<=5	31538	19695	17309	139	202517	202378	241		
6-10	48171	29975	2419	373	219649	219276	231	-1.79	-8.18
11-15	49162	26230	531	990	216355	215365	231	0.00	-6.69
16-20	34190	16674	135	2279	156309	154030	223	-1.38	-5.06
21-25	18257	8406	24	4041	90762	86721	211	-2.20	-4.52
26-30	12726	5383	36	6428	66917	60489	211	0.03	-3.21
31-35	8567	3790	24	13162	55630	42468	202	-1.67	0.10
36-40	2743	1095	7	11772	26291	14519	189	-2.60	-6.51
41+	1295	495	0	6507	11286	4779	271	15.40	13.24
TOTAL	206649	111743	20485	45691	1045716	1000025			
					Average annual quit rate			-0.8%	

SOURCE: 1983, 1985 and 1987 Survey of Doctorate Recipients.

Table A-18. Summary Projections in Biomedical Sciences

Biomedical Sensitivity Model

Model Assumptions	High	Mid	Low
1. Federal health R&D funding growth	4.0%	2.7%	0.2%
2. Private health R&D funding growth	13.0%	9.0%	5.0%
3. Other health R&D funding growth	4.0%	3.0%	2.0%
4. Grad and undergrad, biomed enrollment	1.0%	0.0%	-1.0%
5. "Other" biomed R&D employment growth	3.5%	2.5%	1.5%
6. "Other" biomed non R&D employ. growth	10.0%	8.0%	5.0%

Projected Employment of Biomedical Scientists, 1973-2000 (in 100s of workers)

	Low Case			Mid Case			High Case		
Year	Total	R&D	% R&D	Total	R&D	% R&D	Total	R&D	% R&D
1973	396.4	197.8	49.9%	396.4	197.8	49.9%	396.4	197.8	49.9%
1975	447.2	211.8	47.4%	447.2	211.8	47.4%	447.2	211.8	47.4%
1977	479.2	237.9	49.6%	479.2	237.9	49.6%	479.2	237.9	49.6%
1979	543.8	284.5	52.3%	543.8	284.5	52.3%	543.8	284.5	52.3%
1981	600.1	316.2	52.7%	600.1	316.2	52.7%	600.1	316.2	52.7%
1983	626.4	322.1	51.4%	626.4	322.1	51.4%	626.4	322.1	51.4%
1985	703.2	366.7	52.1%	703.2	366.7	52.1%	703.2	366.7	52.1%
1987	762.6	437.6	57.4%	762.6	437.6	57.4%	762.6	437.6	57.4%
1988	786.4	451.2	57.4%	802.4	464.0	57.8%	816.6	475.3	58.2%
1989	791.6	459.0	58.0%	823.3	484.1	58.8%	851.6	506.5	59.5%
1990	811.1	466.8	57.6%	858.7	504.2	58.7%	901.7	538.1	59.7%
1991	825.0	474.6	57.5%	888.8	524.4	59.0%	947.8	570.9	60.2%
1992	839.3	482.4	57.5%	919.9	545.2	59.3%	996.8	605.9	60.8%
1993	855.2	490.4	57.3%	953.6	566.9	59.4%	1050.7	643.9	61.3%
1994	869.6	498.5	57.3%	987.2	589.8	59.7%	1107.5	685.7	61.9%
1995	886.5	506.8	57.2%	1024.6	614.1	59.9%	1171.5	732.1	62.5%
1996	894.9	515.4	57.6%	1055.3	640.1	60.6%	1232.7	783.7	63.6%
1997	913.2	524.3	57.4%	1097.9	668.1	60.8%	1310.3	841.4	64.2%
1998	928.8	533.5	57.4%	1140.0	698.3	61.3%	1392.5	906.0	65.1%
1999	947.4	543.1	57.3%	1187.7	731.0	61.6%	1486.0	978.4	65.8%
2000	973.6	553.1	56.8%	1245.6	766.5	61.5%	1596.4	1059.6	66.4%
Growth Rates:									
73-87	4.8%	5.8%		4.8%	5.8%		4.8%	5.8%	
87-91	2.0%	2.0%		3.9%	4.6%		5.6%	6.9%	
87-20	1.9%	1.8%		3.8%	4.4%		5.8%	7.0%	

NOTE: This table does not include those in postdoctoral training positions or who are unemployed.
SOURCE: Estimated by NRC.

Table A-19. Historical and Projected Vacancy Ratios, 1973-2000, Biomedical Scientists

	Annual Averages					
	Total			R&D		
Year	Vacancies	PhDs	Ratio	Vacancies	Post-docs	Ratio
1973-78	3455	3499	0.99	2344	2868	0.82
1978-83	3957	3763	1.05	2863	3788	0.76
1983-87	4846	3862	1.25	4157	4072	1.02
1987-95						
Low	4067	3662	1.11	3086	3900	0.79
Mid	5955	3969	1.50	4626	3900	1.19
High	8063	4298	1.88	6386	3900	1.64

NOTE: Assumes that Ph.D. production changes in proportion to enrollment assumptions and postdoc production remains constant.

SOURCE: Estimated by NRC.

Table A-20. Summary Projections for Nonclinical Psychology Sensitivity Model

Model Assumptions	High	Mid	Low
1. Graduate student enrollment	1.0%	0.0%	-1.0%
2. Industrial employment growth	4.0%	3.0%	2.0%

Projected Employment of Nonclinical Psychologists, 1973-2000 (in 100s of workers)

	Low Case			Mid Case			High Case		
Year	Total	R&D	% R&D	Total	R&D	% R&D	Total	R&D	% R&D
1973	129.0	38.8	30.0%	129.0	38.8	30.0%	129.0	38.8	30.0%
1975	148.1	39.5	26.6%	148.1	39.5	26.6%	148.1	39.5	26.6%
1977	153.2	43.1	28.1%	153.2	43.1	28.1%	153.2	43.1	28.1%
1979	157.9	49.4	31.3%	157.9	49.4	31.3%	157.9	49.4	31.3%
1981	179.9	50.2	27.9%	179.9	50.2	27.9%	179.9	50.2	27.9%
1983	187.2	47.7	25.5%	187.2	47.7	25.5%	187.2	47.7	25.5%
1985	191.0	46.8	24.5%	191.0	46.8	24.5%	191.0	46.8	24.5%
1987	198.4	55.7	28.1%	198.4	55.7	28.1%	198.4	55.7	28.1%
1988	200.0	54.9	27.5%	200.3	55.0	27.5%	200.7	55.2	27.5%
1989	195.5	54.0	27.6%	202.2	55.5	27.4%	204.9	56.1	27.4%
1990	195.2	53.9	27.6%	204.0	55.9	27.4%	209.2	57.1	27.3%
1991	194.9	53.9	27.6%	206.0	56.3	27.4%	213.6	58.1	27.2%
1992	194.8	53.8	27.6%	207.9	56.8	27.3%	218.2	59.2	27.1%
1993	194.7	53.8	27.6%	210.0	57.2	27.3%	223.0	60.2	27.0%
1994	194.7	53.8	27.6%	212.1	57.7	27.2%	227.9	61.3	26.9%
1995	194.8	53.7	27.6%	214.2	58.2	27.2%	232.9	62.5	26.8%
1996	194.9	53.7	27.6%	216.4	58.7	27.1%	238.1	63.6	26.7%
1997	195.1	53.7	27.5%	218.7	59.2	27.0%	243.4	64.8	26.6%
1998	195.4	53.8	27.5%	221.0	59.7	27.0%	249.0	66.1	26.5%
1999	195.8	53.8	27.5%	223.4	60.2	26.9%	254.7	67.4	26.5%
2000	199.2	54.5	27.3%	225.9	60.7	26.9%	260.6	68.7	26.4%
Growth Rates:									
73-87	3.1%	2.6%		3.1%	2.6%		3.1%	2.6%	
87-91	-0.4%	-0.9%		0.9%	0.3%		1.9%	1.0%	
87-20	0.0%	-0.2%		1.0%	0.7%		2.1%	1.6%	

NOTE: This table does not include postdoctoral employment or unemployment.
SOURCE: Estimated by NRC.

Table A-21. Historical and Projected Vacancy Ratios, 1973-2000, Nonclirical Psychologists

	Annual Averages					
	Total			R&D		
Year	Vacancies	PhDs	Ratio	Vacancies	Post-docs	Ratio
1973-78	1189	1592	0.75	385	196	1.96
1978-83	1386	1555	0.89	359	226	1.59
1983-87	1291	1435	0.90	422	261	1.61
1990-95						
Low	995	1260	0.79	320	300	1.07
Mid	1252	1366	0.92	380	300	1.27
High	1551	1479	1.05	449	300	1.50

NOTE: Assumes that Ph.D. production changes in proportion to enrollment assumptions and postdoc production remains constant. Graduate model

SOURCE: Estimated by NRC.

Table A-22. Summary Projections for Other Behavioral Scientists

Model Assumptions		High	Mid	Low
1. Graduate student enrollment		1.0%	0.0%	-1.0%
2. "All other" employment growth				
	R&D	7.0%	5.0%	3.0%
	NonR&D	15.0%	10.0%	7.0%

Projected Employment of Other Behavioral Scientists, 1973-2000 (in 100s of workers)

	Low Case			Mid Case			High Case		
Year	Total	R&D	% R&D	Total	R&D	% R&D	Total	R&D	% R&D
1973	65.9	12.1	18.4%	65.9	12.1	18.4%	65.9	12.1	18.4%
1975	82.0	14.4	17.6%	82.0	14.4	17.6%	82.0	14.4	17.6%
1977	100.8	19.6	19.5%	100.8	19.6	19.5%	100.8	19.6	19.5%
1979	108.5	24.8	22.9%	108.5	24.8	22.9%	108.5	24.8	22.9%
1981	108.2	22.2	20.5%	108.2	22.2	20.5%	108.2	22.2	20.5%
1983	124.8	19.0	15.3%	124.8	19.0	15.3%	124.8	19.0	15.3%
1985	126.9	18.5	14.6%	126.9	18.5	14.6%	126.9	18.5	14.6%
1987	127.4	24.0	18.9%	127.4	24.0	18.9%	127.4	24.0	18.9%
1988	126.8	23.2	18.3%	129.0	23.6	18.3%	131.4	24.0	18.2%
1989	126.4	23.2	18.3%	130.7	23.9	18.3%	135.8	24.7	18.2%
1990	126.1	23.1	18.4%	132.6	24.3	18.3%	140.6	25.6	18.2%
1991	125.9	23.2	18.4%	134.7	24.7	18.4%	145.9	26.4	18.1%
1992	125.8	23.2	18.4%	137.0	25.2	18.4%	151.6	27.4	18.1%
1993	125.9	23.2	18.4%	139.5	25.6	18.4%	158.0	28.4	17.9%
1994	126.0	23.3	18.5%	142.2	26.1	18.4%	165.0	29.4	17.8%
1995	126.4	23.3	18.5%	145.1	26.6	18.3%	172.8	30.5	17.6%
1996	126.8	23.4	18.5%	148.3	27.1	18.3%	181.5	31.7	17.4%
1997	127.4	23.5	18.4%	151.8	27.7	18.2%	191.1	32.9	17.2%
1998	128.2	23.6	18.4%	155.7	28.3	18.2%	201.9	34.2	16.9%
1999	129.1	23.7	18.4%	159.9	28.9	18.1%	213.9	35.6	16.6%
2000	130.2	23.8	18.3%	164.4	29.5	18.0%	227.4	37.1	16.3%
Growth Rates:									
73-87	4.8%	5.0%		4.8%	5.0%		4.8%	5.0%	
87-91	-0.3%	-0.9%		1.4%	0.7%		3.4%	2.4%	
87-20	0.2%	-0.1%		2.0%	1.6%		4.6%	3.4%	

NOTE: This table does not include postdoctoral employment or unemployment.
SOURCE: Estimated by NRC.

Table A-23. Historical and Projected Vacancy Ratios, 1973-2000, Other Behavioral Scientists

	Annual Averages					
	Total			R&D		
Year	Vacancies	PhDs	Ratio	Vacancies	Post-docs	Ratio
1973-78	1152	1211	0.95	289	97	2.97
1978-83	930	1093	0.85	120	124	0.97
1983-87	875	943	0.93	185	120	1.54
1987-95						
Low	649	814	0.80	142	120	1.18
Mid	927	882	1.05	191	120	1.59
High	1353	955	1.42	250	120	2.08

NOTE: Assumes that Ph.D. production changes in proportion to enrollment assumptions and postdoc production remains constant.
Graduate model

SOURCE: Estimated by NRC.

Table A-24. Classifications of Fields

NIH[a]

BIOMEDICAL SCIENCES

General Medical and Biological Sciences

* Anatomy
* Biochemistry
* Biophysics
* Microbiology
* Pathology
* Pharmacology
* Physiology
Multidisciplinary[b]
Radiation, Nonclin.
Entomology
* Genetics
* Nutrition
Hydrobiology
Ecology
* Cell Biology
* Zoology
Botany
* Biology NEC
* Other Gen. Med. and Bio. Sci.
* Environ. Sciences
* Toxicology

Mathematics, Physical Sciences, Engineering, Other

Mathematics
Chemistry
Physics
Earth and Related Sciences
Agricultural Fields
Engineering
Engineering, Health-Related

Other Health-Related Fields

* Biostatistics
* Epidemiology

Community and Environmental Health

Accident Prevention
Disease Prevention and Control
Maternal & Child Health
Dental Public Health
Mental Health
Hospital & Medical Care
Other Community Health
Radiological Health
Water Pollution Control
Air Pollution
Environmental Engineering
Food Protection
Occupational Health
Health Administration
Social Work
Pharmacy
Other Health-Rel. Profs.
Other Env. Health Fields

ADAMHA[c]

BIOMEDICAL SCIENCES

* **Anatomy**

Anatomy
Histology
Pathology
Experimental Pathology
Cell Biology
Embryology

* **Biology**

Radiobiology
Entomology
Nutrition
Molecular Biology
Zoology
Botany
Developmental Biology
Neurobiology
Teratology
Aging Process
Oral Biology

* **Genetics**

Genetics
Mutagenesis

* **Microbiology/Immunology**

Microbiology
Bacteriology
Immunology
Mycology
Parasitology
Virology

* **Pharmacology**

Pharmacology

* **Physiology**

Physiology
Reproductive Physiology
Endocrinology
Communicative Sciences
Physiological Optics

* **Toxicology**

Toxicology
Aquatic
Environmental
Forensic
Inhalation
Occupational/Safety

Mathematics, Physical Sciences, Engineering, Other

Chemistry

Biochemistry
Biomaterials
Chemistry
Polymer Chemistry
Medicinal Chemistry
Organic Chemistry
Physical Chemistry
Inorganic Chemistry

Physics/Engineering

Biophysics
Radiation Physics
Biomedical Engineering
Environ. Engineering
Physics
Engineering

Other Health-Related Fields

Statistics/Epidemiology/Computer Sciences

* Biostatistics
* Epidemiology
Information Sciences
Mathematics
Statistics
Computer Sciences

NAS[d]

* **BASIC BIOMEDICAL SCIENCES**

Anatomy
Embryology
Human and Animal Physiology
Biochemistry
Molecular Biology
Biomathematics
Biometrics and Biostatistics
Biomedical Engineering
Biophysics
Environmental Sciences
Environmental Health
General Biological Sciences
Human and Animal Genetics
Immunology
Parasitology
Microbiology
Bacteriology
Neurosciences
Human and Animal Pathology
Pharmaceutical Chemistry
Human and Animal Pharmacology
Pharmacy
Public Health
Epidemiology
Hospital Administration
Veterinary Medicine
Zoology
Cell Biology/Cytology
Nutritional Sciences/Dietetics
Food Science and Technology
Endocrinology
Toxicology
Other Biological Sciences
Medicine and Surgery
Dentistry
Optometry, Ophthalmology
General Health, Medical Sciences
Other Health/Medical Sciences

Table A-24. Classifications of Fields (continued)

NIH[a]	ADAMHA[c]	NAS[d]
BEHAVIORAL SCIENCES	BEHAVIORAL SCIENCES	BEHAVIORAL SCIENCES
Psychology	Psychology	Psychology
General and Experimental	Experimental and General	General
Comparative and Animal	Psychophysics	Clinical
Physiological	Physiological Psychology and Psychobiology	Cognitive
Developmental	Developmental and Child	Counseling and Guidance
Personality	Personality	Developmental and
Gerontological		
Social-Psychological Aspects	Social	Educational
Abnormal	Community and Ecological	School
Clinical		Experimental
Education, Counseling, and Guidance	Other Behavioral Sciences	Comparative
Other Psychological		Physiological
	Health Administration and Public Health	Psychometrics
Other Behavioral Sciences	Education and Guidance	Quantitative
	Sociology	Social
Sociology	Demography or Population Dynamics	Industrial and Organizational
Social Psychology-Sociological Aspects	Anthropology	Personality
Anthropology	Linguistics	Human Engineering
Social Sciences and Related Disciplines	Social Sciences and Related Disciplines	Behavior/Ethology
Other Fields	Economics	Other Psychology
	Political Science	
CLINICAL SCIENCES	Bioethics	Other Behavioral Sciences
	Social/Behavioral Sciences	
Internal Medicine		Anthropology
Allergy	CLINICAL SCIENCES	Sociology
Pediatrics		Audiology and Speech Pathology
Geriatrics	Psychiatry	
Obstetrics-Gynecology	Other Clinical Medicine	
Radiology	Nursing	
Surgery	Social Work	
Otorhinolaryngology	Clinical Psychology	
Ophthalmology		
Anesthesiology		
Neuropsychiatry		
Neurology		
Psychiatry		
Preventive Medicine		
Other Clinical Medicine		
Veterinary Medicine		
Clinical Dentistry		
NURSING RESEARCH		

* These fields correspond to those defined by the committee as the Basic Biomedical Sciences. See NRC (1975-81, 1977 Report, p. 29).

[a] Since 1962, NIH has used a classification scheme called the Discipline/Specialty/Field Code (DSF) to classify areas of training for its trainees and fellows. The major categories of that scheme are shown in this table. They have been grouped into 4 broad areas of research that the committee has established for purposes of this study.

[b] Most of the trainees in the Medical Scientist Training Program are classified in this category.

[c] These fields represent the lexicon established by ADAMHA to classify areas of training for its NRSA trainees and fellows.

[d] These fields are used by the National Research Council's Survey of Doctorates and Survey of Doctorate Recipients to identify fields of Ph.D. specialization and fields of employment.

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